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(71)出願人　000004226
日本電信電話株式会社
東京都新宿区西新宿三丁目19番2号

(72)発明者　高良　秀彦
東京都新宿区西新宿三丁目19番2号　日本電信電話株式会社内

(72)発明者　社家　一平
東京都新宿区西新宿三丁目19番2号　日本電信電話株式会社内

(72)発明者　山林　由明
東京都新宿区西新宿三丁目19番2号　日本電信電話株式会社内

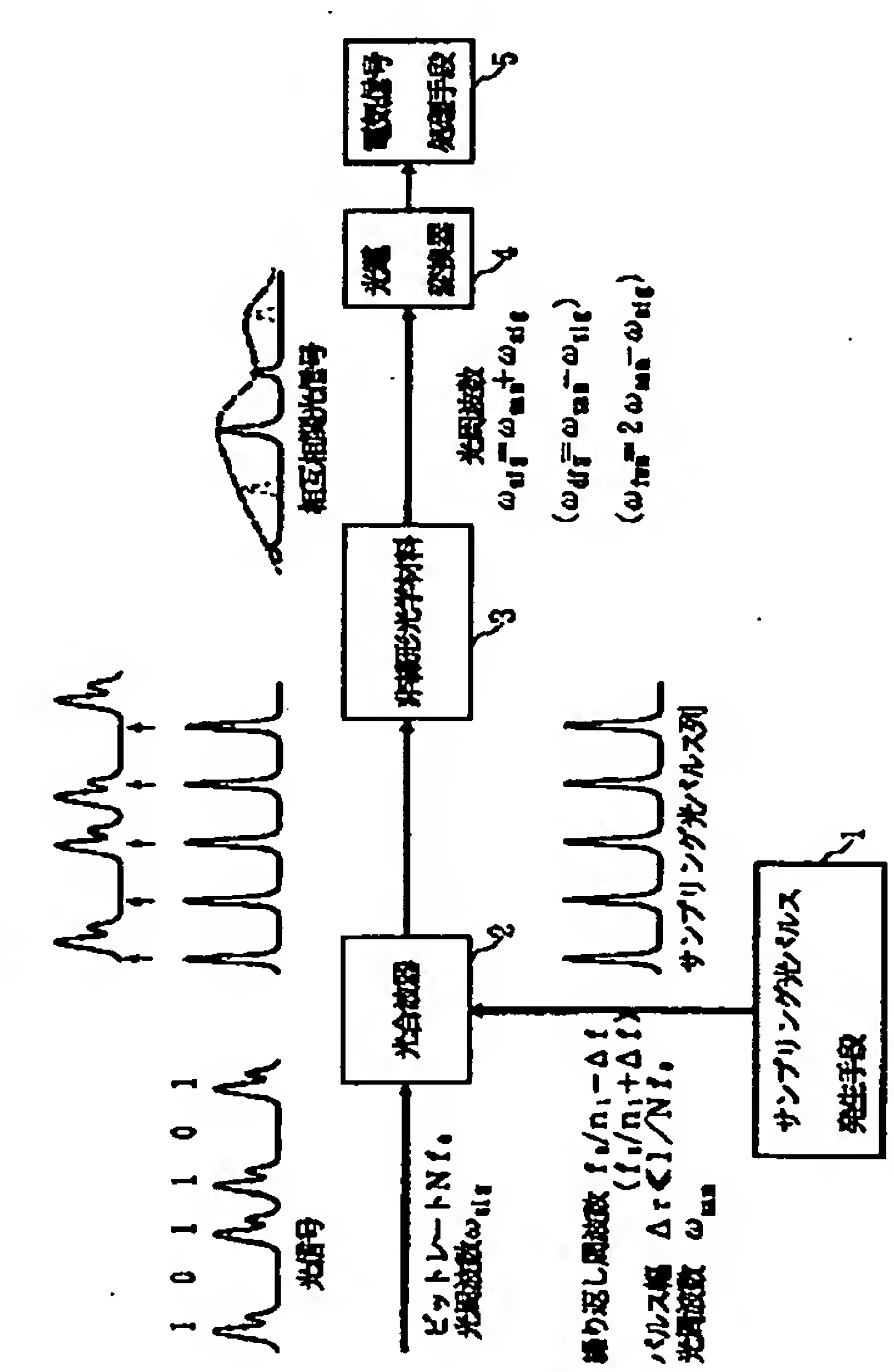
(74)代理人　弁理士　古谷　史旺

(54)【発明の名称】　光信号品質モニタ

(57)【要約】

【課題】　光信号のビットレートによらず、単一の測定系で光信号の品質検査を行う。また、数十Gbit/s 以上のビットレートの光信号にも対応する。さらに、伝送路の光信号の信号対雑音比に与える影響を低減する。

【解決手段】　繰り返し周波数 $f_0/n_1-\Delta f$ (Hz) を有するサンプリング光パルス列と、ビットレート $N\cdot f_0$ (bit/s) の光信号を合波して非線形光学材料に入力し、非線形光学効果により生じる相互相関光信号を出力させ、これを相互相関電気信号に変換し、電気信号処理手段でこの相互相関電気信号より光強度のヒストグラムを測定し、そのヒストグラムを構成するサンプリング点から「レベル１」と「レベル０」それぞれのある平均時間内での平均値レベルの差と、「レベル１」と「レベル０」それぞれの当該平均時間内での標準偏差値の和の比を信号対雑音比係数として求め、光信号の品質を検査する。


本発明の光信号品質モニタの基本構成

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【特許請求の範囲】

【請求項１】　基本クロック周波数f_0(Hz)の整数分の１とわずかに異なる繰り返し周波数$f_0/n_1-\Delta f$ (Hz) または$f_0/n_1+\Delta f$ (Hz) を有するサンプリング光パルス列を発生するサンプリング光パルス発生手段と、

前記基本クロック周波数f_0(Hz)の整数倍のビットレート$N\cdot f_0$ (bit/s) を有する光信号と、前記サンプリング光パルス列とを合波する光合波器と、

前記光合波器で合波された前記光信号および前記サンプリング光パルス列を入力し、非線形光学効果により生じる相互相関光信号を出力することで前記光信号を前記サンプリング光パルス列でサンプリングする非線形光学材料と、

前記相互相関光信号を相互相関電気信号に変換する光電変換器と、

前記相互相関電気信号より光強度のヒストグラムを測定し、その光強度ヒストグラムを構成するサンプリング点から「レベル１」と「レベル０」それぞれのある平均時間内での平均値レベルの差と、「レベル１」と「レベル０」それぞれの当該平均時間内での標準偏差値の和の比を信号対雑音比係数として求め、前記光信号の品質を検査する電気信号処理手段とを備えたことを特徴とする光信号品質モニタ。

【請求項２】　基本クロック周波数f_0(Hz)の整数倍のビットレート$N\cdot f_0$ (bit/s) を有する光信号を電気信号に変換する光電変換器と、

前記基本クロック周波数f_0(Hz)の整数分の１とわずかに異なる繰り返し周波数$f_0/n_1-\Delta f$ (Hz) または$f_0/n_1+\Delta f$ (Hz) のタイミングクロックを発生するタイミングクロック発生手段と、

前記タイミングクロックで前記電気信号のレベルをサンプリングしてそのヒストグラムを測定し、そのヒストグラムを構成するサンプリング点から「レベル１」と「レベル０」それぞれのある平均時間内での平均値レベルの差と、「レベル１」と「レベル０」それぞれの当該平均時間内での標準偏差値の和の比を信号対雑音比係数として求め、前記光信号の品質を検査する電気信号処理手段とを備えたことを特徴とする光信号品質モニタ。

【請求項３】　請求項１または請求項２に記載の光信号品質モニタにおいて、

電気信号処理手段は、ヒストグラムを構成するサンプリング点のうち、あらかじめ定めた閾値レベルより高い点群を「レベル１」とし、また別途定めた閾値レベルより低い点群を「レベル０」とし、「レベル１」と「レベル０」それぞれのある平均時間内での平均値レベルの差μと、「レベル１」と「レベル０」それぞれの当該平均時間内での標準偏差値の和$(\sigma_1+\sigma_0)$の比

$Q=\mu/(\sigma_1+\sigma_0)$

を信号対雑音比係数として求める構成であることを特徴とする光信号品質モニタ。

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【請求項４】　請求項３に記載の光信号品質モニタにおいて、

電気信号処理手段は、あらかじめ特定の時間内に測定したサンプリング点からレベルのヒストグラムを求め、このヒストグラムのレベル最大値からサンプリング点数を積分し、全サンプリング点数をN_{total}、光信号のデューティ比（パルス幅とタイムスロットの比）をD、マーク率（ディジタル伝送における「レベル１」の発生確率）をMとしたときに、

$N_{middle}=N_{total}\times D\times M$

で求まるサンプリング点数N_{middle}と等しくなったときのレベルを中間値μ_mとし、

前記ヒストグラムにおいてレベル最小値側から最初にサンプリング点数がピーク値となるレベルを「レベル０」の平均値μ_0とし、

「レベル０」および「レベル１」の閾値レベルμ_{th0}，μ_{th1}を

$\mu_{th0}=2\alpha\mu_m+(1-2\alpha)\mu_0$

$\mu_{th1}=2(1-\alpha)\mu_m-(1-2\alpha)\mu_0$

$0.1<\alpha<0.4$

とすることを特徴とする光信号品質モニタ。

【請求項５】　請求項１または請求項２に記載の光信号品質モニタにおいて、

電気信号処理手段は、ヒストグラムを構成するサンプリング点のうち、あらかじめ定めた２つの領域のうち高いレベル領域内の点群を「レベル１」とし、低いレベル領域内の点群を「レベル０」とし、「レベル１」と「レベル０」それぞれのある平均時間内での平均値レベルの差μ'と、「レベル１」と「レベル０」それぞれの当該平均時間内での標準偏差値の和$(\sigma_1+\sigma_0)$の比

$Q=\mu'/(\sigma_1+\sigma_0)$

を信号対雑音比係数として求める構成であることを特徴とする光信号品質モニタ。

【請求項６】　請求項５に記載の光信号品質モニタにおいて、

電気信号処理手段は、あらかじめ特定の時間内に測定したサンプリング点からレベルのヒストグラムを求め、このヒストグラムのレベル最大値からサンプリング点数を積分し、全サンプリング点数をN_{total}、光信号のデューティ比（パルス幅とタイムスロットの比）をD、マーク率（ディジタル伝送における「レベル１」の発生確率）をMとしたときに、

$N_{middle}=N_{total}\times D\times M$

で求まるサンプリング点数N_{middle}と等しくなったときのレベルを中間値μ_mとし、

前記ヒストグラムにおいてレベル最小値側から最初にサンプリング点数がピーク値となるレベルを「レベル０」の平均値μ_0とし、

「レベル０」および「レベル１」の閾値レベルμ_{th0}，

μ_{th1} を
$\mu_{th0}=2\alpha\mu_{m}+(1-2\alpha)\mu_{0}$
$\mu_{th1}=2(1-\alpha)\mu_{m}-(1-2\alpha)\mu_{0}$
$0.1<\alpha<0.4$
とし、
前記特定の時間内に測定したサンプリング点の中でレベルの最大値と最小値をそれぞれμ_{max}，μ_{min}とし、「レベル０」の範囲をμ_{min}以上μ_{th0}以下とし、「レベル１」の範囲をμ_{th1}以上μ_{max}以下とすることを特徴とする光信号品質モニタ。

【請求項７】　請求項１に記載の光信号品質モニタにおいて、
相互相関光信号は、非線形光学効果により発生させた和周波光、または差周波光、または四光波混合光であることを特徴とする光信号品質モニタ。

【請求項８】　請求項１に記載の光信号品質モニタにおいて、
サンプリング光パルス発生手段は、
伝送路から分岐した光信号の基本クロック周波数f_0(Hz)の整数分の１からオフセット周波数Δf(Hz)を加減した周波数$f_0/n_1-\Delta f$ (Hz)または$f_0/n_1+\Delta f$ (Hz)のタイミングクロックを発生するタイミングクロック発生手段と、
前記タイミングクロックを用いて、繰り返し周波数$f_0/n_1-\Delta f$ (Hz)または$f_0/n_1+\Delta f$ (Hz)で、パルス幅が光信号のタイムスロットより十分に狭いサンプリング光パルス列を発生する短光パルス発生手段とを備えたことを特徴とする光信号品質モニタ。

【請求項９】　請求項２または請求項８に記載の光信号品質モニタにおいて、
タイミングクロック発生手段は、
伝送路から分岐した光信号から抽出したクロック信号の基本クロック周波数f_0(Hz)をf_0/n_1(Hz)に分周する分周器と、
n_1，n_2を自然数とし、δTをサンプリングステップ時間としたときに、
$\Delta f=f_0(n_1+f_0\delta T)/n_1(n_1+n_2+f_0\delta T)$
で表されるオセセット周波数Δfで発振する発振器と、
前記分周されたクロック信号と前記発振器の出力とを混合し、周波数$f_0/n_1\pm\Delta f$(Hz)のタイミングクロックを生成するミキサと、
前記ミキサ出力から$f_0/n_1-\Delta f$(Hz)または$f_0/n_1+\Delta f$(Hz)の周波数成分のみを出力するバンドパスフィルタとを備えたことを特徴とする光信号品質モニタ。

【請求項１０】　請求項１に記載の光信号品質モニタにおいて、
サンプリング光パルス発生手段は、
基本クロック周波数f_0(Hz)の整数分の１のクロック周波数f_0/m (Hz)を有する同期網クロック信号を入力し、基本クロック周波数の整数分の１からオフセット周波数Δf (Hz)を加減した周波数$f_0/n_1-\Delta f$ (Hz)または$f_0/n_1+\Delta f$ (Hz)のタイミングクロックを発生するタイミングクロック発生手段と、
前記タイミングクロックを用いて、繰り返し周波数$f_0/n_1-\Delta f$ (Hz)または$f_0/n_1+\Delta f$ (Hz)で、パルス幅が光信号のタイムスロットより十分に狭いサンプリング光パルス列を発生する短光パルス発生手段とを備えたことを特徴とする光信号品質モニタ。

【請求項１１】　請求項２または請求項１０に記載の光信号品質モニタにおいて、
タイミングクロック発生手段は、
クロック周波数f_0/m (Hz)の同期網クロック信号を基本クロック周波数f_0(Hz)の整数分の１の周波数f_0/n_1(Hz)に逓倍または分周する逓倍器または分周器と、
n_1，n_2を自然数とし、δTをサンプリングステップ時間としたときに、
$\Delta f=f_0(n_1+f_0\delta T)/n_1(n_1+n_2+f_0\delta T)$
で表されるオセセット周波数Δfで発振する発振器と、
前記逓倍または分周されたクロック信号と前記発振器の出力とを混合し、周波数$f_0/n_1\pm\Delta f$(Hz)のタイミングクロックを生成するミキサと、
前記ミキサ出力から$f_0/n_1-\Delta f$(Hz)または$f_0/n_1+\Delta f$(Hz)の周波数成分のみを出力するバンドパスフィルタとを備えたことを特徴とする光信号品質モニタ。

【請求項１２】　請求項２，８，１０のいずれかに記載の光信号品質モニタにおいて、
タイミングクロック発生手段は、
基本クロック周波数f_0(Hz)の整数分の１の周波数f_0/n_1(Hz)から、n_1，n_2を自然数とし、δTをサンプリングステップ時間としたときに、
$\Delta f=f_0(n_1+f_0\delta T)/n_1(n_1+n_2+f_0\delta T)$
で表されるオセセット周波数Δfを加減した周波数$f_0/n_1-\Delta f$ (Hz)または$f_0/n_1+\Delta f$(Hz)で発振する発振器を備えたことを特徴とする光信号品質モニタ。

【請求項１３】　請求項８または請求項１０に記載の光信号品質モニタにおいて、
伝送路から光信号の一部を分岐する光分岐器を備え、
前記光分岐器で分岐された光信号とサンプリング光パルス発生手段から出力されたサンプリング光パルス列とを光合波器で合波する構成であることを特徴とする光信号品質モニタ。

【請求項１４】　請求項１３に記載の光信号品質モニタにおいて、
光合波器は、光信号およびサンプリング光パルス列をそれぞれ直交する２つの偏光成分（Psig.p, Psig.s）、（Psam.p, Psam.s）に分離し、さらにその互いに直交する成分同士（Psig.p, Psam.s）、（Psig.s, Psam.p）を偏光合成して２つの出力ポートに出力する偏波分離合成手段であり、

前記偏波分離合成手段から出力される２系統の偏光合成光に対して、それぞれ相互相関光信号を発生させ、さらに相互相関電気信号に変換する２系統の非線形光学材料および光電変換器と、
前記２系統の相互相関電気信号を加算して電気信号処理手段に送出する加算回路とを備えたことを特徴とする光信号品質モニタ。
【請求項１５】　請求項１３に記載の光信号品質モニタにおいて、
光合波器は、光信号およびサンプリング光パルス列をそれぞれ直交する２つの偏光成分（Psig.p，Psig.s）、（Psam.p，Psam.s）に分離し、さらにその互いに直交する成分同士（Psig.p，Psam.s）、（Psig.s，Psam.p）を偏光合成して２つの出力ポートに出力する偏波分離合成手段であり、
前記偏波分離合成手段から出力される２系統の偏光合成光に対して、それぞれ相互相関光信号を発生させる２系統の非線形光学材料と、
前記２系統の相互相関光信号のタイミングを合わせて偏光合成して光電変換器に送出する偏波合成手段とを備えたことを特徴とする光信号品質モニタ。
【請求項１６】　請求項８または請求項１０に記載の光信号品質モニタにおいて、
光合波器および非線形光学材料は伝送路に挿入され、伝送路からの光信号とサンプリング光パルス発生手段から出力されたサンプリング光パルス列とを光合波器で合波して非線形光学材料に入力し、
伝送路に挿入され、前記非線形光学材料から出力される光信号と相互相関光信号とを分離し、光信号を伝送路に送出し、相互相関光信号を光電変換器に送出する波長分離手段を備えたことを特徴とする光信号品質モニタ。
【請求項１７】　請求項１６に記載の光信号品質モニタにおいて、
光合波器は、光信号およびサンプリング光パルス列をそれぞれ直交する２つの偏光成分（Psig.p，Psig.s）、（Psam.p，Psam.s）に分離し、さらにその互いに直交する成分同士（Psig.p，Psam.s）、（Psig.s，Psam.p）を偏光合成して２つの出力ポートに出力する偏波分離合成手段であり、
前記偏波分離合成手段から出力される２系統の偏光合成光に対して、それぞれ相互相関光信号を発生させ、さらに光信号と相互相関光信号とを分離する２系統の非線形光学材料および波長分離手段と、
前記２系統の光信号のタイミングを合わせて偏光合成して伝送路に送出する偏波合成手段と、
前記２系統の相互相関光信号を相互相関電気信号に変換する２系統の光電変換器と、
前記２系統の相互相関電気信号を加算して電気信号処理手段に送出する加算回路とを備えたことを特徴とする光信号品質モニタ。
【請求項１８】　請求項１６に記載の光信号品質モニタにおいて、
光合波器は、光信号およびサンプリング光パルス列をそれぞれ直交する２つの偏光成分（Psig.p，Psig.s）、（Psam.p，Psam.s）に分離し、さらにその互いに直交する成分同士（Psig.p，Psam.s）、（Psig.s，Psam.p）を偏光合成して２つの出力ポートに出力する偏波分離合成手段であり、
前記偏波分離合成手段から出力される２系統の偏光合成光に対して、それぞれ相互相関光信号を発生させ、さらに光信号と相互相関光信号とを分離する２系統の非線形光学材料および波長分離手段と、
前記２系統の光信号のタイミングを合わせて偏光合成して伝送路に送出する第１の偏波合成手段と、
前記２系統の相互相関光信号のタイミングを合わせて偏光合成して光電変換器に送出する第２の偏波合成手段とを備えたことを特徴とする光信号品質モニタ。
【発明の詳細な説明】
【０００１】
【発明の属する技術分野】本発明は、異なったビットレートのディジタル光信号が伝送される光ファイバ伝送ネットワークにおいて、光信号の信号対雑音比をモニタする光信号品質モニタに関する。
【０００２】
【従来の技術】1990年代に世界的統一ネットワーク階梯構造となったＳＤＨ（Synchronous Digital Hierarchy）では、ビットインターリーブパリティと呼ばれるパリティ検査を中継器間（ＢＩＰ－８）、多重化端局相互間（ＢＩＰ－Ｎ×24）でそれぞれ実施することにより、故障区間の同定と切替起動信号を得ている。ここで、Ｎは多重化数を表すＳＴＭ－ＮのＮであり、156 Mbit/s のＳＴＭ－１を基本とし、その整数倍の階梯をＳＴＭ－Ｎと表す。なお、Ｎ＝１，４，16，64が国際的に認知されている。ＢＩＰ－Ｍは、Ｍビットおきのパリティ検査を意味し、Ｍビットの検査ビットが得られる。送信側でフレーム内の信号のＭビット並列のパリティ検査を実行し、その検査ビットを次のフレームに格納して主信号とともに伝送する。受信側では、同様のパリティ検査を行い、次フレームの所定位置に格納された検査ビットと照合することにより伝送誤りを検出する。
【０００３】図１８は、従来の誤り率測定系の構成例を示す。図において、伝送路からの光信号の一部が光分岐器５１－１で分岐され、光増幅器５２で増幅され、さらに光分岐器５１－２で２分岐される。光分岐器５１－２で分岐された一方の光信号はクロック抽出回路５３に入力され、光信号のビットレートＮf_0に応じたクロックf_0が抽出される。光分岐器５１－２で分岐された他方の光信号は受信回路５４に入力され、さらにその出力がフレーム検出回路，パリティ検査回路および照合回路からなる誤り率検出回路５５に入力される。受信回路５４

および誤り率検出回路５５は、クロック抽出回路５３で抽出されたクロックf_0に応じて動作し、光信号の誤り率を測定する。なお、クロック抽出回路５３、受信回路５４、誤り率検出回路５５は、光信号のビットレートに応じた構成のものが必要である。すなわち、複数のビットレートに対応した誤り率検出を行うためには、各ビットレートに対応した回路を用意する必要があり、単一の回路で対応することはできない。

【０００４】ところで、伝送システムの評価を行うには、信号の誤り率を直接測定する方法が一般的である。しかし、この方法では、非常に低い誤り率の場合に測定時間が長くかかることになり、作業効率が低くなる問題があった。

【０００５】そこで、識別器の閾値を変化させたときに得られる誤り率の傾向から最適動作点での誤り率を推定する方法が考案された（参考文献１：N.S.Bergano et al.,"Margin Measurement in Optical Amplifier Systems", IEEE Photonics Technology Letters, vol.5, no.3, pp.304-306）。図１９に光信号のアイパタンおよび光強度ヒストグラムを示す。このアイパタンのアイ開口が最大になる時点（識別ポイント）において、識別器の閾値を変化させることにより、２値伝送の場合の「ハイ」または「１」レベルと、「ロー」または「０」レベルの判別を行い、そのときの誤りの割合を測定する。

【０００６】実際には、図２０に示すようなクロック抽出回路５３、光電変換器５６、電気信号処理手段５７による測定系を構成し、誤り率の閾値依存性から信号対雑音比に相当するＱ値を求めて評価指標としている。すなわち、伝送路からの光信号の一部を光電変換器５６で電気信号に変換し、この電気信号とクロック抽出回路５３で抽出されたクロックをサンプリングオシロスコープのような電気信号処理手段５７に入力し、図１９のようなアイパタンおよび光強度ヒストグラムを得る。

【０００７】このアイパタンのアイ開口が最大となる時間t_0において、信号振幅（例えば電圧値）を$\mu(t_0)$とし、２値伝送の場合の「ハイ」または「１」レベルの雑音の標準偏差を$\sigma_1(t_0)$、「ロー」または「０」レベルの雑音の標準偏差を$\sigma_0(t_0)$としたときに、$Q(t_0)$値は

$$Q(t_0)=\mu(t_0)/(\sigma_1(t_0)+\sigma_0(t_0)) \quad \cdots(1)$$

で定義される。一方、ガウス型の雑音振幅分布を仮定すると、誤り率の低い領域では誤り率ＰとＱ値は、

$$P=(1/(Q(2\pi)^{1/2}))\exp(-Q^2/2) \quad \cdots(2)$$

のような関係がある。したがって、Ｑ値が測定できれば、伝送路誤り率が推定できることになる。

【０００８】

【発明が解決しようとする課題】しかし、従来のＱ値測定系は、図２０に示すように光信号を電気信号に変換した後に波形をサンプリングしてＱ値を求めているので、光電変換器や電気信号処理回路の帯域や処理速度により、対応できる光信号のビットレートが40Gbit/s程度に制限されていた。

【０００９】また、アイ開口が最大となる時点でのＱ値を測定するので、異なるビットレートのディジタル光信号には対応できなかった。また、従来のＱ値測定系は、伝送路からモニタ用の光信号を分岐する必要があるので、伝送路上の光信号に分岐による損失が生じ、信号対雑音比を劣化させる要因になっている。

【００１０】本発明は、異なったビットレートのディジタル光信号が伝送される光ファイバ伝送ネットワークにおいて、被測定光信号のビットレートによらず単一の回路で信号対雑音比をモニタすることができる光信号品質モニタを提供することを目的とする。

【００１１】また、本発明は、数十Gbit/s 以上のビットレートの光信号にも対応することができる光信号品質モニタを提供することを目的とする。また、本発明は、伝送路の光信号の信号対雑音比に与える影響を低減することができる光信号品質モニタを提供することを目的とする。

【００１２】

【課題を解決するための手段】請求項１に記載の光信号品質モニタは、光学的手段により光信号のビットレートによらない光強度ヒストグラムから、サンプリング点の振幅値の統計処理値から信号対雑音比をモニタする構成である。以下、その基本構成について説明する。

【００１３】図１は、請求項１に記載の光信号品質モニタの基本構成を示す。図において、伝送路から入力される光信号は、光周波数ω_{sig}、基本クロック周波数f_0(Hz)の整数倍のビットレート$N\cdot f_0$(bit/s)（Ｎ＝１，２，…）を有する。サンプリング光パルス発生手段１は、光周波数$\omega_{s.p.}$、基本クロック周波数f_0(Hz)の整数分の１とオフセット周波数Δf（Hz）を加減した繰り返し周波数$f_0/n_1-\Delta f$（Hz）（または$f_0/n_1+\Delta f$（Hz））（n_1＝１，２，…）で、パルス幅$\Delta\tau$が光信号のタイムスロットより十分に狭い（$\Delta\tau \ll 1/Nf_0$）サンプリング光パルスを発生する。光合波器２は、光信号とサンプリング光パルスを合波して非線形光学材料３に入力する。

【００１４】非線形光学材料３は、２次の非線形光学効果の一つである和周波光発生（ＳＦＧ：Sum Frequency Generation）（参考文献２：高良　他、「和周波光発生を用いた光サンプリングによる超高速光波形測定法」、電子情報通信学会論文誌、Ｂ－Ｉ、vol.J75-B-I, no.5, pp.372-380, 1992)や差周波光発生（ＤＦＧ：Defference Frequency Generation ）、３次の非線形光学効果である四光波混合（ＦＷＭ：Four Wave Mixing）（参考文献３：P.A.Andrekson, Electron.Lett.27, p.1440, 1991)を利用し、光信号とサンプリング光パルスの相互相関光信号を発生させる。

【００１５】図２(a),(b),(c) は、それぞれＳＦＧ，ＤＦＧ，ＦＷＭにおける光周波数の関係を示す。ＳＦＧ

は、図２(a) に示すように、光周波数ω_{sig}の光信号と光周波数ω_{sam}のサンプリング光パルスの２光波を２次の非線形光学材料に入射すると、和の光周波数ω_{sfg}（$=\omega_{sam}+\omega_{sig}$）の光が発生する現象である。ＤＦＧは、図２(b) に示すように、光周波数ω_{sig}の光信号と光周波数ω_{sam}のサンプリング光パルスから差の光周波数ω_{dfg}（$=\omega_{sam}-\omega_{sig}$）の光が発生する現象である。

【００１６】ＦＷＭは、一般に３つの入射光（光周波数$\omega_1, \omega_2, \omega_3$)から新たな光（光周波数$\omega_4=\omega_1+\omega_2-\omega_3$）が発生する現象であるが、光サンプリングに応用する場合には３種類の光を用いるのは構成が複雑になるので、通常２つの光波が縮退（$\omega_1=\omega_2$）したＦＷＭを利用する。すなわち、ω_1，ω_2 として光周波数ω_{sam}のサンプリング光パルスを入射し、ω_3 として光周波数ω_{sig}の光信号を入射することにより、図２(c) に示すように、光周波数ω_{fwm}（$=2\omega_{sam}-\omega_{sig}$)の光を発生させる。

【００１７】ここで、サンプリング光パルスの繰り返し周波数が光信号の基本クロック周波数f_0の$1/n_1$に比べてΔfだけ小さいので、サンプリング光パルスは光信号との相対位置をずらしながら掃引することになる。その結果、相互相関光信号は図１に示すように変化し、その包絡線は光信号波形の時間軸を拡大した波形となる。この相互相関光信号を受光系で検出することにより、高速光信号の光強度のヒストグラムの測定が可能となる（上記参考文献２）。

【００１８】すなわち、相互相関光信号を光電変換器４で電気信号に変換して電気信号処理手段５に入力する。電気信号処理手段５では、相互相関電気信号のピーク値の検出および分析を行い、図３に示すような光強度のヒストグラムを測定する。そして、この光強度のヒストグラムを構成するサンプリング点のうち、あらかじめ定めた閾値レベルμ_{th1}より高い点群を「レベル１」とし、また別途定めた閾値レベルμ_{th0}より低い点群を「レベル０」とし、「レベル１」と「レベル０」それぞれのある平均時間内での平均値μ_1，μ_0の差μと、「レベル１」と「レベル０」それぞれの当該平均時間内での標準偏差値の和（$\sigma_1+\sigma_0$）の比

$$Q=\mu/(\sigma_1+\sigma_0) \quad \cdots(3)$$

を信号対雑音比係数として求める（請求項３）。

【００１９】ここで、上記の閾値レベルμ_{th1}，μ_{th0}を決定する方法の一例について、図４を参照して説明する（請求項４）。まず、電気信号処理手段５は、あらかじめ特定の時間内に測定したサンプリング点からレベルのヒストグラムを求め、このヒストグラムのレベル最大値からサンプリング点数を積分し、サンプリング点数N_{middle}と等しくなったときのレベルを中間値μ_mとする。なお、サンプリング点数N_{middle}は、全サンプリング点数をN_{total}、光信号のデューティ比（パルス幅とタイムスロットの比）をＤ、マーク率（ディジタル伝送におけるマーク「１」の発生確率）をＭとしたときに、

$$N_{middle}=N_{total}\times D\times M \quad \cdots(4)$$

として求める。また、「レベル１」の平均値μ_1は、

$$\mu_1=2(\mu_m-\mu_0)+\mu_0 \quad \cdots(5)$$

と仮定する。

【００２０】次に、上記ヒストグラムにおいてレベル最小値側から最初にサンプリング点数がピーク値となるレベルを「レベル０」の平均値μ_0とする。また、「レベル０」および「レベル１」の閾値レベルμ_{th0}，μ_{th1}を

$$\mu_{th0}=\mu_0+\alpha(\mu_1-\mu_0)$$
$$\mu_{th1}=\mu_1-\alpha(\mu_1-\mu_0) \quad \cdots(6)$$

と設定する。ただし、$0<\alpha<0.5$ とする。この (6)式に (5)式を代入すると、

$$\mu_{th0}=2\alpha\mu_m+(1-2\alpha)\mu_0$$
$$\mu_{th1}=2(1-\alpha)\mu_m-(1-2\alpha)\mu_0 \quad \cdots(7)$$

が得られる。

【００２１】以上の方法で決定した閾値レベルμ_{th0}，μ_{th1}と全測定値から求めた光強度のヒストグラムにより、「レベル１」と「レベル０」の平均値μ_1，μ_0および標準偏差σ_1，σ_0を求め、これらの値から平均的な信号対雑音比係数（Ｑ値）を求める。

【００２２】この信号対雑音比係数Ｑは、光信号の信号対雑音比に１対１に対応する物理量である。したがって、このＱ値を求めることにより、伝送してきた光信号の品質を検査することができる。

【００２３】図５は、上記方法で求めた平均的なＱ値と、時間t_0におけるＱ値との関係を示す。図より、αを0.1 にするとサンプリング点数が減少するため、平均的なＱ値のばらつきが大きくなる。一方、αが 0.4以上になるとアイパタンのクロスポイント付近の測定値が含まれるので、平均的なＱ値の値が低くなり測定精度が悪くなる。これに対して、 $0.1<\alpha<0.4$ の場合は、サンプリング点数も十分であり、クロスポイントの影響も回避できるので、平均的なＱ値と時間t_0におけるＱ値の間によい相関が得られる。なお、この例では相関係数として0.99の高い値が得られている。

【００２４】したがって、(7) 式において、 $0.1<\alpha<0.4$ と設定して各閾値レベルμ_{th0}，μ_{th1}を決定することにより、精度よく伝送路の光信号品質を監視することができる。

【００２５】また、図６に示すように、ヒストグラムを構成するサンプリング点のうち、あらかじめ定めた２つの領域のうち高いレベル領域内の点群を「レベル１」とし、低いレベル領域内の点群を「レベル０」とし、「レベル１」と「レベル０」それぞれのある平均時間内での平均値レベルの差μ'と、「レベル１」と「レベル０」それぞれの当該平均時間内での標準偏差値の和（$\sigma_1+\sigma_0$）の比

$Q=\mu' / (\sigma_1+\sigma_0)$ …(8)

を信号対雑音比係数として求めてもよい（請求項５）。

【００２６】なお、この場合には、例えばあらかじめ特定の時間内に測定したサンプリング点の中で、最大値と最小値をそれぞれμ_{max}，μ_{min}とすると、図７に示すように、「レベル１」の範囲を「μ_{th1}以上μ_{max}以下」とし、「レベル０」の範囲を「μ_{min}以上μ_{th0}以下」とすればよい（請求項６）。

【００２７】以上説明したように、本発明は、従来行われていたアイパタン開口の最も良好な時点で光信号のビットレートに等しい周波数でデータの取り込みおよび判別を行う誤り率測定法とは異なるものである。すなわち、本発明の光信号品質モニタは、光信号をサンプリングして光強度のヒストグラムを求め、このヒストグラムから時間平均化した信号対雑音比係数（Ｑ値）をモニタするものであり、基本クロック周波数f_0(Hz)の任意の整数倍のビットレートNf_0(bit/s) の光信号に対応することができる。また、パルス幅の狭いサンプリング光パルスおよび高速応答の非線形光学効果による光領域でのサンプリングを利用することで、従来技術では困難であった数十Gbit/s 以上の超高速の光信号の品質も検査することができる。

【００２８】

【発明の実施の形態】（第１の実施形態：請求項１，７，８，９，13）図８は、本発明の光信号品質モニタの第１の実施形態を示す。

【００２９】図において、伝送路から基本クロック周波数f_0(Hz)の整数倍のビットレート$N\cdot f_0$(bit/s)（N＝１，２，…）を有する光信号が入力され、その光信号の一部が光分岐器５１－１で分岐される。このとき、伝送路ポートに対するモニタポートの分岐比は、分岐損失による伝送特性劣化を抑圧するためにできるだけ小さい方がよい。光分岐器５１－１のモニタポートから出力される光信号は、さらに光分岐器５１－２で２分岐される。

【００３０】光分岐器５１－２で分岐された一方の光信号は、タイミングクロック発生手段１１に入力され、基本クロック周波数f_0(Hz)を抽出し、その整数分の１からオフセット周波数Δf(Hz)を引いた（または加えた）タイミングクロック$f_0/n_1-\Delta f$ (Hz)（または$f_0/n_1+\Delta f$ (Hz)）を発生する。短光パルス発生手段１２は、このタイミングクロックを用いて、繰り返し周波数が$f_0/n_1-\Delta f$ (Hz)（または$f_0/n_1+\Delta f$ (Hz)）でパルス幅が光信号のタイムスロットより十分に狭いサンプリング光パルス列を発生する。

【００３１】光分岐器５１－２で分岐された他方の光信号と短光パルス発生手段１２から出力されたサンプリン＊グ光パルス列は、光合波器２で合波されて非線形光学材料３に入力する。非線形光学材料３は、光信号とサンプリング光パルスの相互相関光信号（ＳＦＧ，ＤＦＧ，ＦＷＭ）を発生させる。この相互相関光信号は、光電変換器４で相互相関電気信号に変換されて電気信号処理手段５に入力される。電気信号処理手段５は、この相互相関電気信号のピーク値の検出および分析を行い、図３に示すようなヒストグラムを測定する。電気信号処理手段５では、上述した原理に基づいて信号対雑音比係数Ｑを求め、光信号の品質を検査する。これにより、異なったビットレートのディジタル光信号が伝送される光ファイバ伝送ネットワークにおいて、光信号のビットレートによらず、単一の測定系で光信号の品質検査を行うことができる。

【００３２】ここで、図１に示す基本構成との対応関係を示す。タイミングクロック発生手段１１および短光パルス発生手段１２は、サンプリング光パルス発生手段１に対応する。その他の同一符号のものはそのまま対応する。なお、本実施形態では、タイミングクロック発生手段１１で光信号の基本クロック周波数f_0を抽出するために、光分岐器５１－１，５１－２を用いて伝送路の光信号の一部を分岐する構成をとっている。

【００３３】図９は、タイミングクロック発生手段の構成例を示す。図９(a) において、基本ビットレートタイミング生成手段１３は、ビットレート$N\cdot f_0$の光信号から基本クロック周波数f_0の整数分の１のクロック周波数f_0/n_1を発生する。発振器１４は、オフセット周波数Δfを発生する。ミキサ１５は、クロック周波数f_0/n_1とオフセット周波数Δfを混合して周波数$f_0/n_1\pm\Delta f$(Hz)のタイミングクロックを生成し、バンドパスフィルタ１８がミキサ出力から$f_0/n_1-\Delta f$(Hz)または$f_0/n_1+\Delta f$(Hz)の周波数成分のみを出力する。

【００３４】ここで、オフセット周波数Δfの設定方法について説明する。図１０は、光信号とサンプリング光および発生した和周波光の時間軸上の関係を示すタイムチャートである。サンプリング光の繰り返し周波数は、光信号の繰り返し周波数f_0の$1/n_1$の分周に比べてΔfだけ小さいので、図１０に示すように、サンプリング光パルスは光信号との相対位置を毎回ΔTずらしながら掃引することになる。この相対位置のずれΔTは、サンプリング光の繰り返し周期$Ts(=1/fs)$と、光信号の$1/n_1$の分周の周期n_1T_0（$T_0=1/f_0$）との差であり、

【００３５】

【数１】

$$\Delta T=Ts-n_1T_0=\frac{1}{\frac{f_0}{n_1}-\Delta f}-\frac{n_1}{f_0}\fallingdotseq\frac{n_1{}^2\Delta f}{f_0{}^2} \quad \cdots(9)$$

【0036】と表される。この相対位置のずれΔTを光信号の周期T_0のn_2倍とサンプリングのステップ時間δTの和とする。すなわち、

$$\Delta T = n_2 T_0 + \delta T \quad \cdots (10)$$

とする。これは、サンプリングのステップ時間δTで光信号波形をサンプリングすることを意味する。このとき、(9)式および(10)式より、Δfは、

【0037】

【数2】

$$\Delta f = \frac{f_0(n_1 + f_0 \delta T)}{n_1(n_1 + n_2 + f_0 \delta T)} \quad \cdots (11)$$

【0038】となる。なお、n_1，n_2は自然数である。したがって、(11)式によりオフセット周波数Δfを設定することにより、所望のサンプリングステップ量δTで光信号波形をサンプリングすることができる。また、n_1およびn_2の組み合わせを適当に選ぶことにより、オフセット周波数およびタイミングクロックをサンプリング光源や信号処理系の帯域に合わせて設定することができる。

【0039】本発明のサンプリングにおける時間分解能は、主に短光パルス発生手段12で発生するサンプリング光パルスのパルス幅Δτと、非線形光学材料3の応答速度に依存する。短光パルス発生手段12としては、モード同期ファイバレーザ、モード同期半導体レーザ、利得スイッチング半導体レーザ等が使用できる。現在、これらの光源を用いることにより、パルス幅1ps以下の短光パルスを発生することができる。非線形光学材料3としては、SFGおよびDFGについて、2次の非線形光学材料であるKTP（分子式$KTiOPO_4$）や$LiNbO_3$等の無機材料、AANP等の有機材料、半導体導波路等が使用できる。FWMについては、3次の非線形光学材料である光ファイバ等の石英系光導波路が使用できる。これらの材料の応答速度はいずれも 0.1ps以下である。したがって、以上のものを使用することにより、時間分解能は1ps以下が可能である。なお、これはビットレート数百Gbit/s に相当する。

【0040】光合波器2としては、通常の光カプラを用いてもよいが、波長多重カプラを用いることにより低損失でサンプリング光パルスと光信号を合波することができる。また、サンプリング光パルスと光信号の偏光方向が直交している場合には、偏波ビームスプリッタにより偏波多重するようにしてもよい。

【0041】なお、非線形光学効果としてSFGまたはDFGを利用する場合には、光信号とサンプリング光パルスの偏光方向により使用できる非線形光学材料が異なる。両光の偏光方向が平行の場合には、2つの基本光の偏光が平行の時に効率よく相互相関光が発生する「タイプI位相整合」を行う2次の非線形光学材料を用いる必要がある。一方、両光の偏光方向が直交の場合には、2つの基本光の偏光が直交の時に効率よく相互相関光が発生する「タイプII位相整合」を行う2次の非線形光学材料を用いる必要がある（上記参考文献2）。非線形光学効果としてFWMを利用する場合には、効率よく相互相関光を発生させるためには、光信号とサンプリング光パルスの偏光方向を平行に設定する必要がある。

【0042】また、使用する非線形光学材料3の変換効率が不十分であれば、光合波器2の前後に配置する光増幅器で光信号およびサンプリング光パルスのピークパワーを増幅すればよい。光増幅器としては、希土類を添加した希土類添加ファイバを用いた光増幅器や半導体レーザ増幅器を用いることができる。

【0043】また、非線形光学材料3の出力光には、相互相関光信号である和周波光（または差周波光または四光波混合光）以外にも、光信号およびサンプリング光パルスが含まれる。また、条件によっては、光信号やサンプリング光パルスの第2次高調波も発生することがある。これらの光が測定する相互相関光信号の信号対雑音比を劣化させる場合には、非線形光学材料3と光電変換器4との間に波長フィルタ32を挿入し、相互相関光信号のみを選択すればよい。

【0044】（第2の実施形態：請求項1，7，10，11，13）図11は、本発明の光信号品質モニタの第2の実施形態を示す。本実施形態の特徴は、第1の実施形態のタイミングクロック発生手段11に代えて、基本クロック周波数f_0の整数分の1のクロック周波数f_0/m（m＝1，2，…）を有する同期網クロック信号から、$f_0/n_1-\Delta f$（または$f_0/n_1+\Delta f$）のタイミングクロックを生成するタイミングクロック発生手段16を用いる構成にある。なお、オフセット周波数Δfは上記の(11)式に基づいて設定すればよい。その他の構成は第1の実施形態と同様である。

【0045】タイミングクロック発生手段16の構成は、図9(b)に示すように、ビットレートf_0/mの網同期クロック信号から、基本クロック周波数f_0の整数分の1のクロック周波数f_0/n_1を発生する基本ビットレートタイミング生成手段17を用いればよい。

【0046】また、第1の実施形態のタイミングクロック発生手段11（図9(a))および第2の実施形態のタイミングクロック発生手段16（図9(b))に代えて、図9(c)に示すように、基本クロック周波数の整数分の1のクロック周波数f_0/n_1から、(11)式のオフセット周波数Δfを加減したタイミングクロック$f_0/n_1-\Delta f$または$f_0/n_1+\Delta f$を発振する発振器をタイミングクロック発生手段として用いてもよい（請求項12）。

【0047】（第3の実施形態：請求項1，7，8，13，14）図12は、本発明の光信号品質モニタの第3の実施形態を示す。本発明で用いる非線形光学効果は一般に偏光依存性を有しており、入力する光信号の偏光状態に応じて発生する相互相関光信号パワーが変化する。本

実施形態は、この偏光依存性を除去する構成になっている。

【００４８】すなわち、第１の実施形態における光合波器２として、入力および出力が２ポートずつある偏波ビームスプリッタ２１を用い、各入力ポートに光信号とサンプリング光パルス列を入力し、各出力ポートに非線形光学材料３－１，３－２、波長フィルタ３２－１，３２－２、光電変換器４－１，４－２を接続し、各光電変換器から出力される相互相関電気信号を加算回路２２で加算して電気信号処理手段５に入力する構成である。

【００４９】ここで、偏波ビームスプリッタ２１に入力するサンプリング光パルス列の偏光は、偏波ビームスプリッタ２１の偏光主軸に対して45度傾いた直線偏光に設定する。このとき、偏波ビームスプリッタ２１に入力された光信号とサンプリング光パルス列は、それぞれ直交する２つの偏光成分（Ｐsig.p，Ｐsig.s）、（Ｐsam.p，Ｐsam.s）に分離される。そして、各出力ポートには２光の互いに直交する成分同士（Ｐsig.p，Ｐsam.s）、（Ｐsig.s，Ｐsam.p）が偏光合成されて出力される。各出力ポートに出力された光信号およびサンプリング光パルス列は、それぞれ個別に設けられた非線形光学材料３－１，３－２で相互相関光信号に変換され、さらに光電変換器４－１，４－２で相互相関電気信号に変換され＊る。これら２系統の相互相関電気信号は、加算回路２２で加算されて電気信号処理手段５に入力され、第１の実施形態と同様に処理して信号対雑音比係数Ｑを求め、光信号の品質を検査する。

【００５０】本実施形態では、サンプリング光パルス列の偏光を偏波ビームスプリッタ２１の偏光主軸に対して45度傾いた直線偏光とすることにより、偏波ビームスプリッタ２１以降の２つの偏光成分Ｐsam.p，Ｐsam.sを等しくしている。すなわち、サンプリング光パルス列の全パワーをＰsam とすると、

$$P_{sam.p} = P_{sam.s} = 0.5 P_{sam} \quad \cdots (12)$$

となる。一方、光信号は、偏波ビームスプリッタ２１に入射する時点の偏光状態が固定されていない。したがって、光信号は偏波ビームスプリッタ２１により、任意のパワー比の２つの偏光成分Ｐsig.p，Ｐsig.sに分離される。ただし、これらの２成分の和は一定であり、光信号の全パワーをＰsig とすると、

$$P_{sig.p} + P_{sig.s} = P_{sig} \quad \cdots (13)$$

となる。

【００５１】ここで、非線形光学効果の変換効率をηとすると、非線形光学材料３－１，３－２で発生する相互相関光信号のパワーの合計Ｐint は、

$$P_{int} = \eta P_{sig.p} P_{sam.s} + \eta P_{sig.s} P_{sam.p} \quad \cdots (14)$$

となる。(14)式に(12)式および(13)式を代入すると、

$$P_{int} = 0.5\eta P_{sig} P_{sam} \quad \cdots (15)$$

となる。この(15)式は、２系統の相互相関光信号の和は、入力される光信号の偏光状態に依存しないことを意味する。

【００５２】ただし、偏波ビームスプリッタ２１の分岐比のずれや、２つの非線形光学材料の変換効率の個体差により(15)式が成立せず、わずかに偏光依存性が生じる場合もある。この場合には、加算された相互相関電気信号のレベルが光信号の偏光状態に依存しないように、加算回路２２において２系統の相互相関電気信号のレベルに適当に重み付けを行えばよい。

【００５３】このような構成で信号対雑音比系列をモニタすることにより、光信号のビットレートによらず、かつ光信号の偏光状態によらずに安定した光信号の品質検査を行うことができる。

【００５４】なお、本実施形態においても、タイミングクロック発生手段１１に代えて、第２の実施形態と同様に、ビットレート f_0/m の網同期クロック信号から $f_0/n_1-\Delta f$（または $f_0/n_1+\Delta f$）のタイミングクロックを生成するタイミングクロック発生手段１６を用いてもよい（請求項10）。また、上述のように発振器のみで構成されるタイミングクロック発生手段を用いてもよい（請求項12）。

【００５５】（第４の実施形態：請求項１，７，８，１３，15）図１３は、本発明の光信号品質モニタの第４の実施形態を示す。本実施形態の特徴は、第３の実施形態の加算回路２２に代えて、２系統の相互相関光信号のタイミングを光遅延手段２３で合わせ、偏波ビームスプリッタ２４で偏波合成して光電変換器４に入力する構成にある。その他の構成は第３の実施形態と同様である。

【００５６】（第５の実施形態：請求項１，７，10，１6）図１４は、本発明の光信号品質モニタの第５の実施形態を示す。第１～第４の実施形態では、伝送路の光信号の品質を検査するために、光分岐器５１－１により光信号の一部を分岐させる必要があり、伝送路の光信号の損失が避けられない。また、この光信号損失を最小限に抑えるためにモニタ系への分岐比を低くすると、光増幅器で増幅しても信号対雑音比が劣化し、十分な相互相関光信号が得られない。

【００５７】本実施形態の特徴は、伝送路にサンプリング光パルス列を入力して相互相関光信号を発生させ、光信号と相互相関光信号を波長分離することにより、伝送路の光信号に与える損失を低減する構成にある。

【００５８】すなわち、タイミングクロック発生手段１６および短光パルス発生手段１２により、ビットレート f_0/m の網同期クロック信号から繰り返し周波数 $f_0/n_1-\Delta f$（または $f_0/n_1+\Delta f$）のサンプリング光パルス列を発生する。一方、伝送路中に光合波器２、非線形光学材料３、波長フィルタ３３を挿入し、上流側の伝送路から送られてきた光信号とサンプリング光パルス列を光合波器２で合波して非線形光学材料３に入力

し、相互相関光信号を発生させる。

【００５９】非線形光学材料３の出力光は、光信号（光周波数ω_{sig}）、サンプリング光パルス（光周波数ω_{sam}）、相互相関光信号である和周波光（光周波数$\omega_{sfg}=\omega_{sam}+\omega_{sig}$）または差周波光（光周波数$\omega_{dfg}=\omega_{sam}-\omega_{sig}$）または四光波混合光（光周波数$\omega_{fwm}=2\omega_{sam}-\omega_{sig}$）である。また、条件によっては、光信号の第２次高調波（光周波数$2\omega_{sig}$）やサンプリング光パルスの第２次高調波（光周波数$2\omega_{sam}$）が発生することもある。波長フィルタ３３は、これらの光から光信号と相互相関光信号を個別に異なるポートに分離する。そして、分離した光信号を下流の伝送路に送出し、相互相関光信号を光電変換器４に入力して相互相関電気信号に変換し、電気信号処理手段５で第１の実施形態と同様に処理して信号対雑音比係数Ｑを求め、光信号の品質を検査する。

【００６０】このような構成で信号対雑音比系列をモニタすることにより、光信号のビットレートによらず、かつ伝送路の光信号の信号対雑音比を劣化させることなく、光信号の品質検査を行うことができる。

【００６１】（第６の実施形態：請求項１，７，10，16，17）図１５は、本発明の光信号品質モニタの第６の実施形態を示す。本実施形態の特徴は、第３の実施形態と第５の実施形態を組み合わせた構成にある。すなわち、光信号の偏光状態に依存せず、かつ伝送路の光信号の損失を低減する構成になっている。

【００６２】上流側の伝送路から送られてきた光信号とサンプリング光パルス列を偏波ビームスプリッタ２１に異なる入力ポートから入射する。このとき、サンプリング光パルス列の偏光は、偏波ビームスプリッタ２１の偏光主軸に対して45度傾いた直線偏光に設定する。偏波ビームスプリッタ２１では、光信号とサンプリング光パルス列はそれぞれ直交する２つの偏光成分（Ｐsig.p，Ｐsig.s）、（Ｐsam.p,Ｐsam.s ）に分離され、２光の互いに直交する成分同士（Ｐsig.p，Ｐsam.s）、（Ｐsig.s，Ｐsam.p）が偏光合成されて異なる出力ポートに出力される。

【００６３】各出力ポートに出力された光信号およびサンプリング光パルス列は、それぞれ個別に設けられた非線形光学材料３－１，３－２で相互相関光信号に変換され、さらに波長フィルタ３３－１，３３－２でそれぞれ光信号と相互相関光信号に分離される。分離された２系統の光信号は、光遅延手段２５でタイミングを合わせ、偏波ビームスプリッタ２６で偏波合成して下流側の伝送路に送出する。一方、分離された２系統の相互相関光信号は、それぞれ光電変換器４－１，４－２で相互相関電気信号に変換され、さらに加算回路２２で加算されて電気信号処理手段５に入力され、第１の実施形態と同様に処理して信号対雑音比係数Ｑを求め、光信号の品質を検査する。

【００６４】このような構成で信号対雑音比系列をモニタすることにより、光信号のビットレートによらず、かつ伝送路の光信号の信号対雑音比を劣化させることなく、さらに光信号の偏光状態によらずに安定した光信号の品質検査を行うことができる。

【００６５】（第７の実施形態：請求項１，７，10，16，18）図１６は、本発明の光信号品質モニタの第７の実施形態を示す。本実施形態の特徴は、第４の実施形態と第５の実施形態を組み合わせた構成にある。すなわち、光信号の偏光状態に依存せず、かつ伝送路の光信号の損失を低減する構成になっている。

【００６６】本実施形態では、第６の実施形態の加算回路２２に代えて、２系統の相互相関光信号のタイミングを光遅延手段２３で合わせ、偏波ビームスプリッタ２４で偏波合成して光電変換器４に入力する構成である。その他の構成は第６の実施形態と同様である。

【００６７】（第８の実施形態：請求項２）図１７は、本発明の光信号品質モニタの第８の実施形態を示す。図において、伝送路から基本クロック周波数f_0(Hz)の整数倍のビットレート$N\cdot f_0$(bit/s)（Ｎ＝１，２，…）を有する光信号が入力され、その光信号の一部が光分岐器５１で分岐される。このとき、伝送路ポートに対するモニタポートの分岐比は、分岐損失による伝送特性劣化を抑圧するためにできるだけ小さい方がよい。光分岐器５１で分岐された光信号は、光電変換器６１で電気信号に変換されて電気信号処理手段６２に入力される。なお、光電変換器６１に入力される光信号の強度が足りなければ、光増幅器を用いて増幅すればよい。

【００６８】タイミングクロック発生手段６３は、基本クロック周波数f_0(Hz)の整数分の１からオフセット周波数Δf(Hz)を加減した周波数$f_0/n_1-\Delta f$（Hz）または$f_0/n_1+\Delta f$（Hz）のタイミングクロックを発生する。なお、タイミングクロック発生手段６３は、図９(a),(b) に示した構成または図９(c) に示した発振器のみの構成のいずれでもよい（請求項９，11，12）。なお、図９(a) の構成をとる場合には、光分岐器５１と光電変換器６１との間に光分岐器を配置し、分岐した光信号をタイミングクロック発生手段６３に入力する。また、図９(b) の構成をとる場合には、同期網クロック信号をタイミングクロック発生手段６３に入力する。

【００６９】電気信号処理手段６２は、このタイミングクロックを用いて電気信号をサンプリングして光強度のヒストグラムを測定する。そして、そのヒストグラムを構成するサンプリング点から「レベル１」と「レベル０」それぞれのある平均時間内での平均値レベルの差と、「レベル１」と「レベル０」それぞれの当該平均時間内での標準偏差値の和の比から時間平均的なＱ値を求め、光信号の品質を検査する。

【００７０】本実施形態の特徴は、図１および上記の各実施形態に示す光段でのサンプリングの代わりに、電気

段でのサンプリングを行うところにある。本実施形態の構成でも、上記の各実施形態と同様に任意のビットレートの光信号の品質監視を行うことができる（請求項３～６）。ただし、対応できる光信号のビットレートは、光電変換器や電気信号処理手段の帯域や処理速度により、数十Gbit/s 程度に制限される。しかし、最高ビットレートがこの制限を越えないことがわかっている光ファイバ伝送ネットワークに対しては適用可能である。

【００７１】

【発明の効果】以上説明したように、本発明の光信号品質モニタは、光信号をサンプリングして光強度のヒストグラムを求め、このヒストグラムより時間平均化した信号対雑音比係数（Ｑ値）をモニタするものであり、また光領域でのサンプリングを利用することで、従来技術では困難であった数十Gbit/s 以上の超高速の光信号の品質を検査することができる。すなわち、１Mbit/s 級から 100Gbit/s 級の広範囲にわたる複数のビットレートの信号の品質を、単一のモニタ回路でモニタすることができる。

【００７２】また、数十Gbit/s 程度までの光信号の品質検査には、電気段でのサンプリングを行う構成によっても信号対雑音比係数（Ｑ値）をモニタすることが可能である。

【００７３】なお、光増幅器を中継器として用いた光ファイバ伝送ネットワークでは、信号ビットレートを柔軟に選択することができるが、本発明の光信号品質モニタはこのような光ファイバ伝送ネットワークにおける光信号の品質をモニタすることができる。また、サンプリング光パルス発生手段が対応できる範囲でビットレートを拡大または改変することにより、ＳＤＨばかりでなくＰＤＨ信号を伝送する伝送路にも適用が可能である。

【図面の簡単な説明】

【図１】本発明の光信号品質モニタの基本構成を示すブロック図。

【図２】ＳＦＧ，ＤＦＧ，ＦＷＭにおける光周波数の関係を示す図。

【図３】電気信号処理手段で測定される光強度ヒストグラムのレベルの設定法を説明する図。

【図４】閾値レベルの決定法を説明する図。

【図５】平均的なＱ値と時間 t_0 におけるＱ値との関係を示す図。

【図６】電気信号処理手段で測定される光強度ヒストグラムのレベルの設定法を説明する図。

【図７】閾値レベルの決定法を説明する図。

【図８】本発明の光信号品質モニタの第１の実施形態を示すブロック図。

【図９】タイミングクロック発生手段の構成例を示すブロック図。

【図１０】光信号とサンプリング光および発生した和周波光の時間軸上の関係を示すタイムチャート。

【図１１】本発明の光信号品質モニタの第２の実施形態を示すブロック図。

【図１２】本発明の光信号品質モニタの第３の実施形態を示すブロック図。

【図１３】本発明の光信号品質モニタの第４の実施形態を示すブロック図。

【図１４】本発明の光信号品質モニタの第５の実施形態を示すブロック図。

【図１５】本発明の光信号品質モニタの第６の実施形態を示すブロック図。

【図１６】本発明の光信号品質モニタの第７の実施形態を示すブロック図。

【図１７】本発明の光信号品質モニタの第８の実施形態を示すブロック図。

【図１８】従来の誤り率測定系の構成例を示すブロック図。

【図１９】光信号のアイパタンおよび光強度ヒストグラムを示す図。

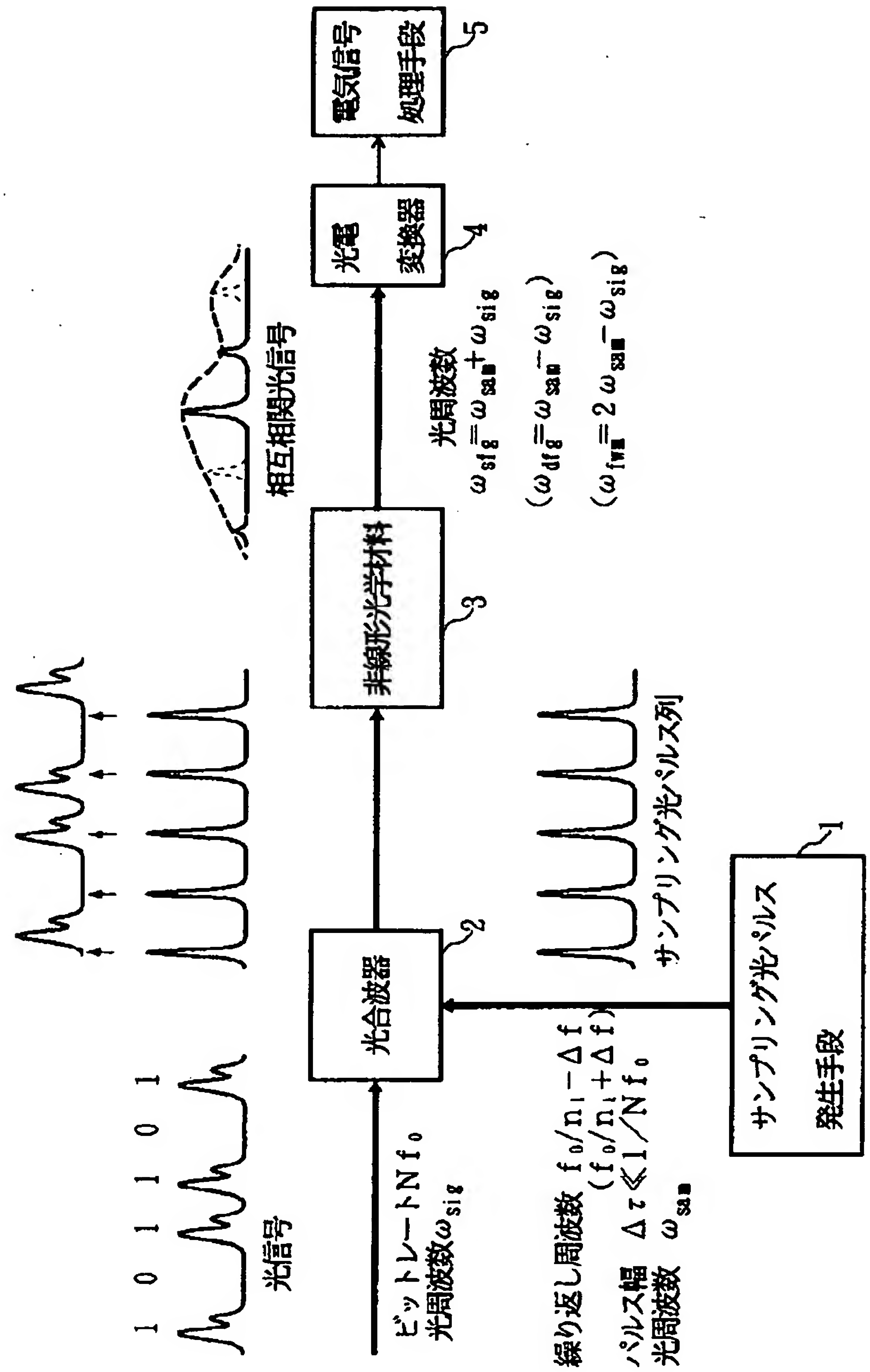
【図２０】光信号のアイパタンの測定系を示すブロック図。

【符号の説明】

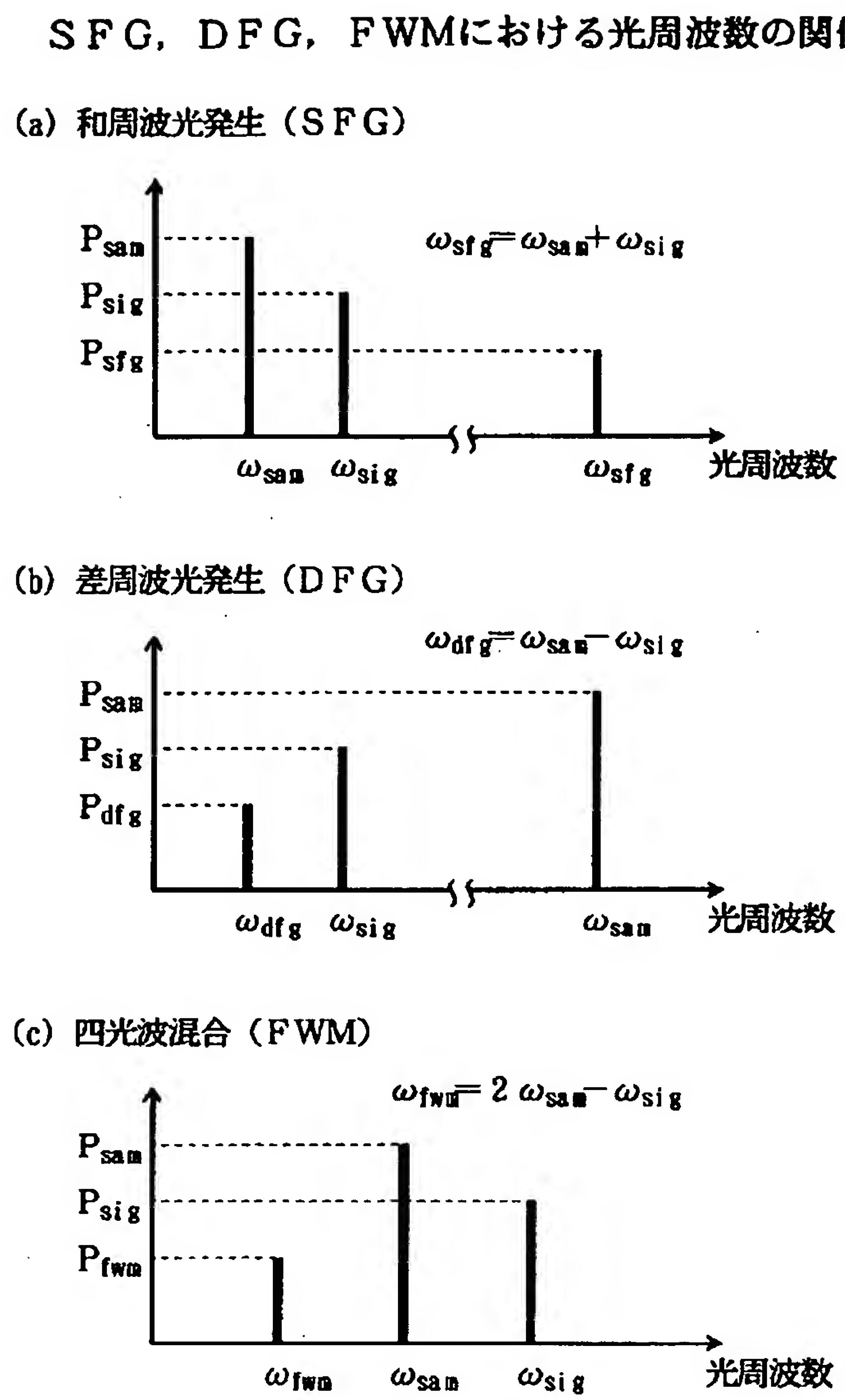
１　サンプリング光パルス発生手段
２　光合波器
３　非線形光学材料
４　光電変換器
５　電気信号処理手段
１１，１６　タイミングクロック発生手段
１２　短光パルス発生手段
１３，１７　基本ビットレートタイミング生成手段
１４　発振器
１５　ミキサ
１８　バンドパスフィルタ
２１，２４，２６　偏波ビームスプリッタ
２２　加算回路
２３，２５　光遅延手段
３２，３３　波長フィルタ
５１　光分岐器
５２　光増幅器
６１　光電変換器
６２　電気信号処理手段
６３　タイミングクロック発生手段

【図１】

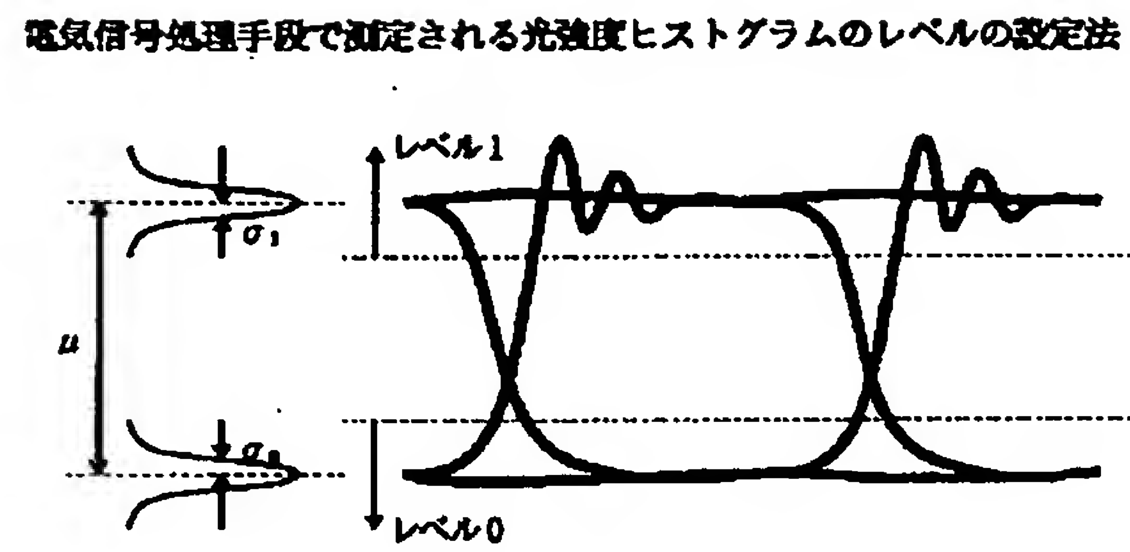
本発明の光信号品質モニタの基本構成



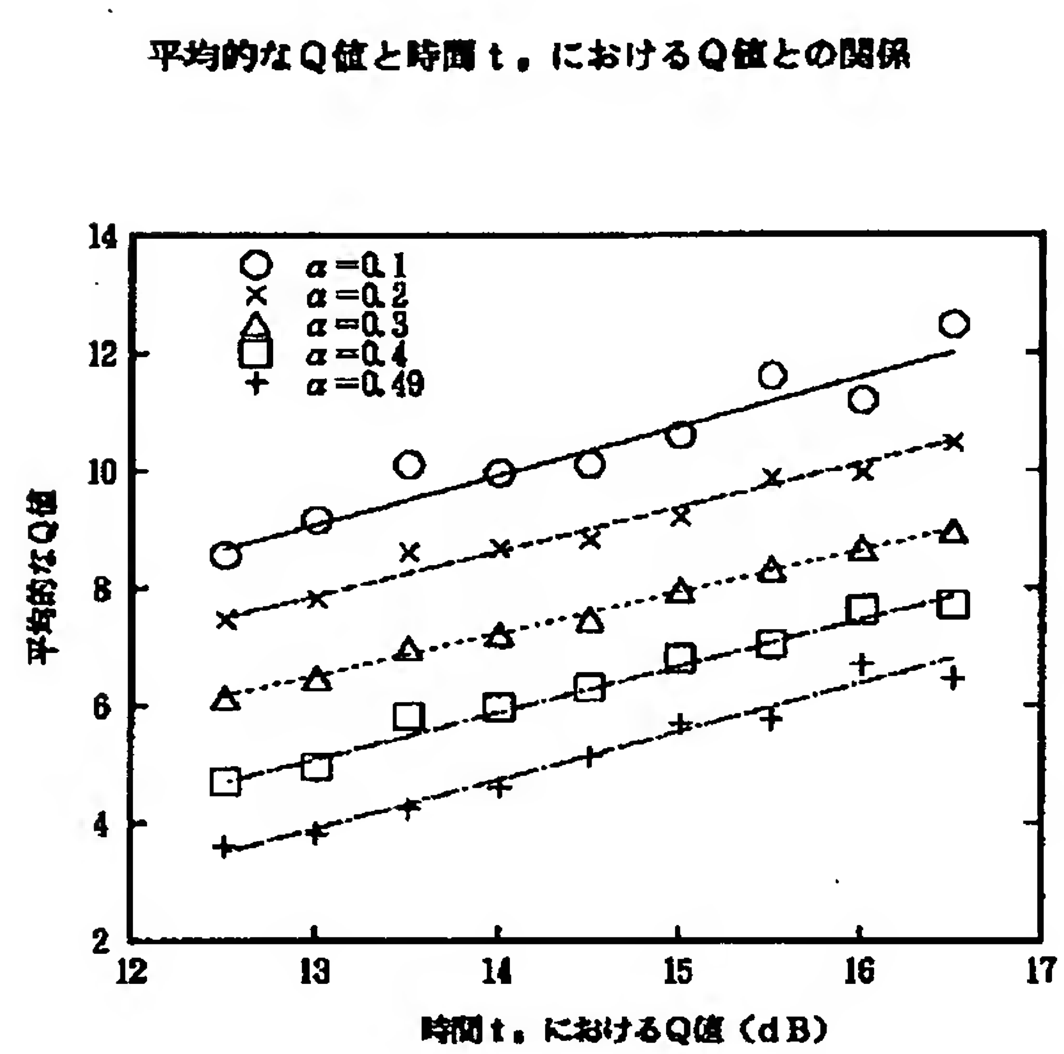
【図２】


ＳＦＧ，ＤＦＧ，ＦＷＭにおける光周波数の関係
(a) 和周波光発生（ＳＦＧ）
$\omega_{sfg}=\omega_{sam}+\omega_{sig}$
P_{sam}
P_{sig}
P_{sfg}
ω_{sam} ω_{sig} ω_{sfg}
光周波数
(b) 差周波光発生（ＤＦＧ）
$\omega_{dfg}=\omega_{sam}-\omega_{sig}$
P_{sam}
P_{sig}
P_{dfg}
ω_{dfg} ω_{sig} ω_{sam}
光周波数
(c) 四光波混合（ＦＷＭ）
$\omega_{fwm}=2\omega_{sam}-\omega_{sig}$
P_{sam}
P_{sig}
P_{fwm}
ω_{fwm} ω_{sam} ω_{sig}
光周波数

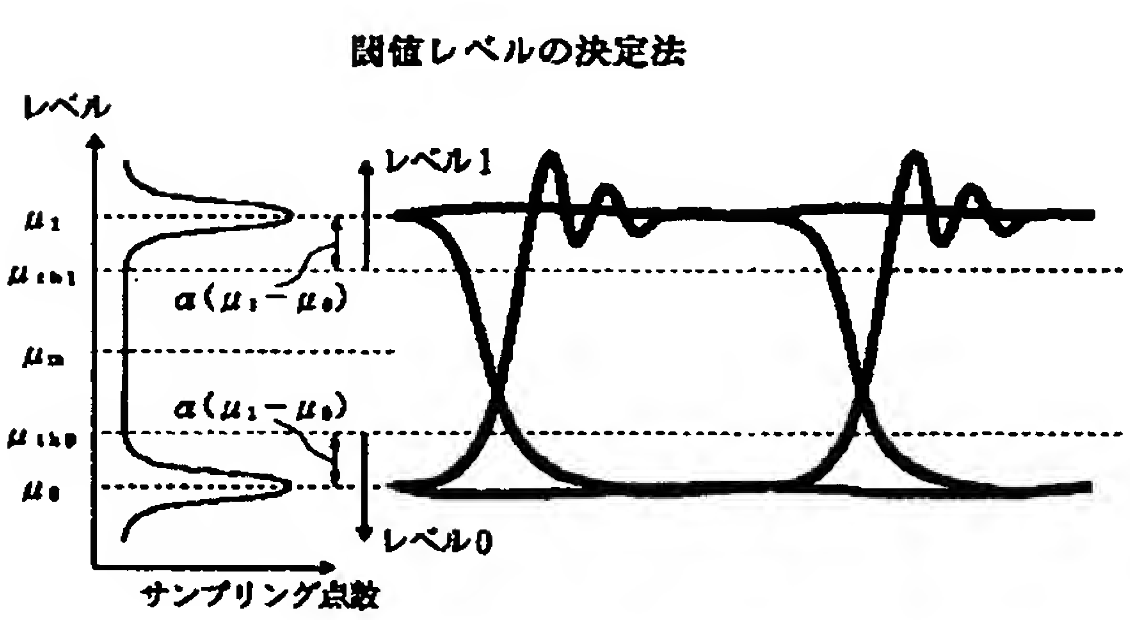
【図３】


電気信号処理手段で測定される光強度ヒストグラムのレベルの設定法
レベル１
σ_1
μ
σ_0
レベル０

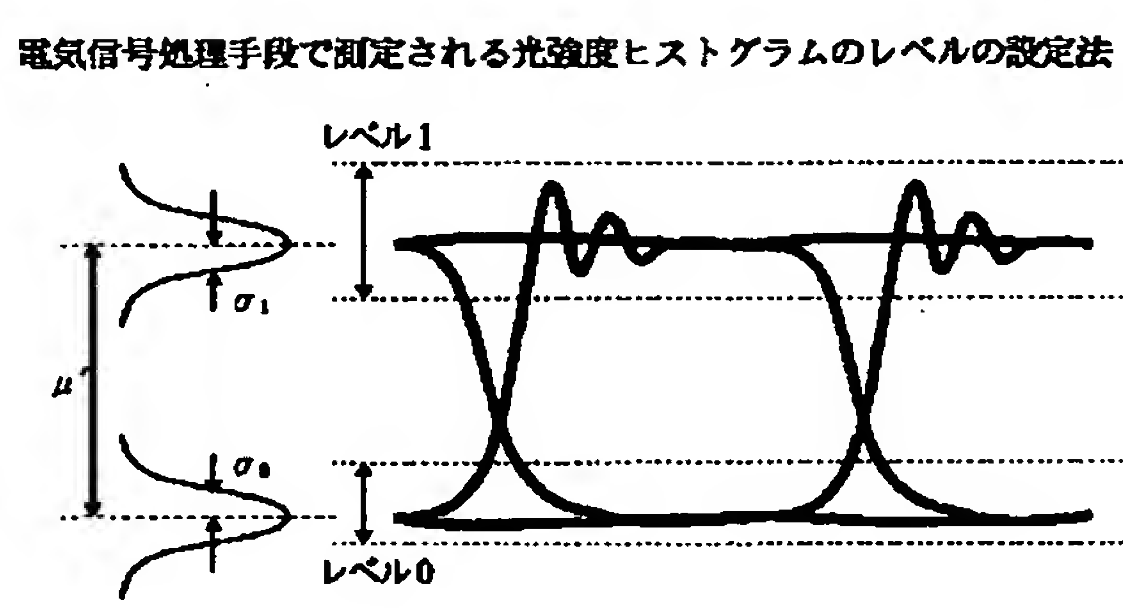
【図５】


平均的なＱ値と時間ｔ。におけるＱ値との関係
α=0.1
α=0.2
α=0.3
α=0.4
α=0.49
平均的なＱ値
時間ｔ。におけるＱ値（ｄＢ）
2
4
6
8
10
12
14
12
13
14
15
16
17

【図４】

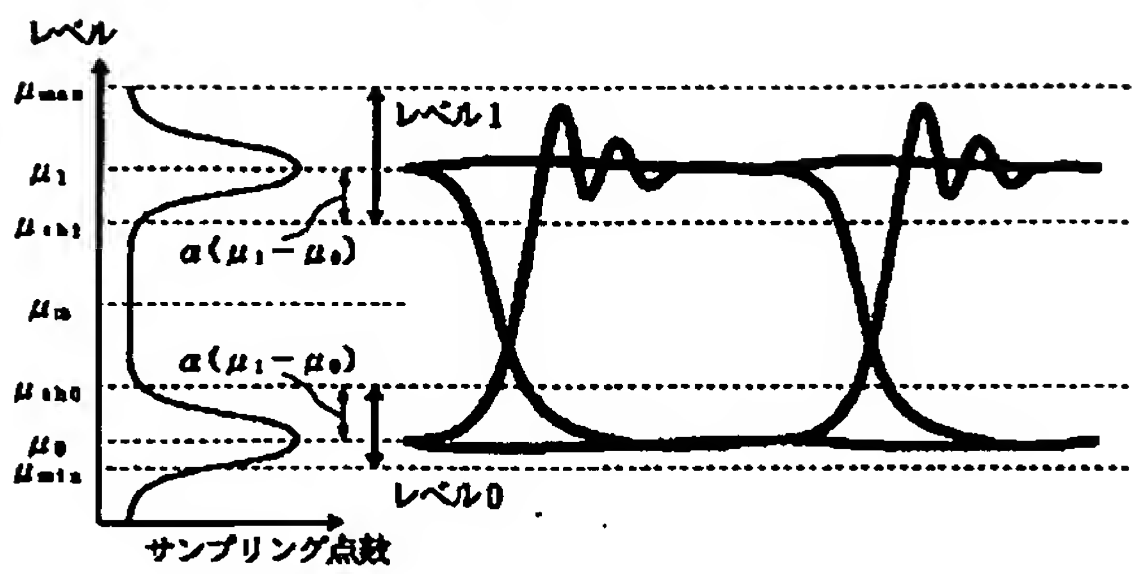

閾値レベルの決定法
レベル
μ_1
μ_{th1}
μ_m
μ_{th0}
μ_0
$\alpha(\mu_1-\mu_0)$
$\alpha(\mu_1-\mu_0)$
レベル１
レベル０
サンプリング点数

【図６】


電気信号処理手段で測定される光強度ヒストグラムのレベルの設定法
レベル１
σ_1
μ'
σ_0
レベル０

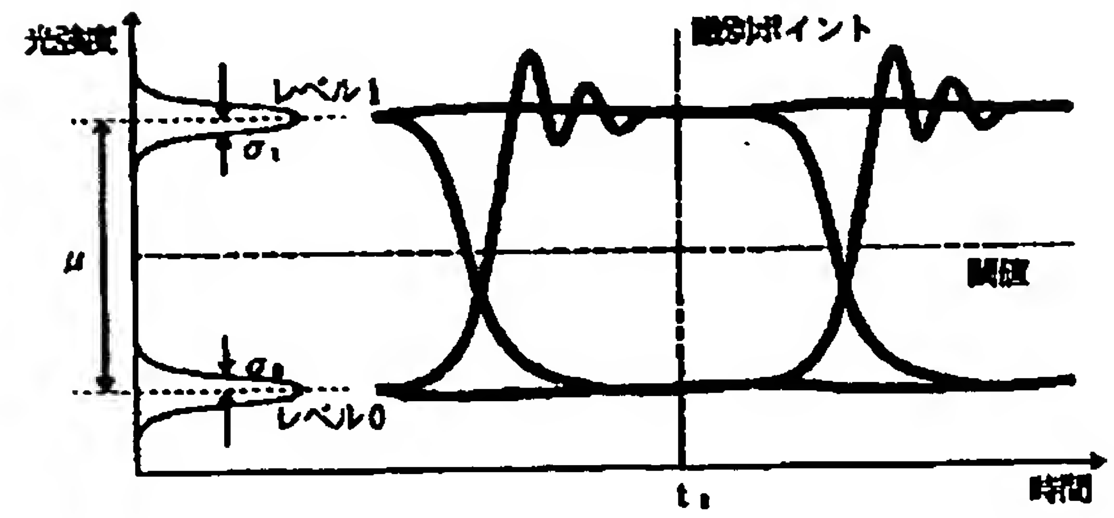
【図７】

閾値レベルの決定法



【図１９】

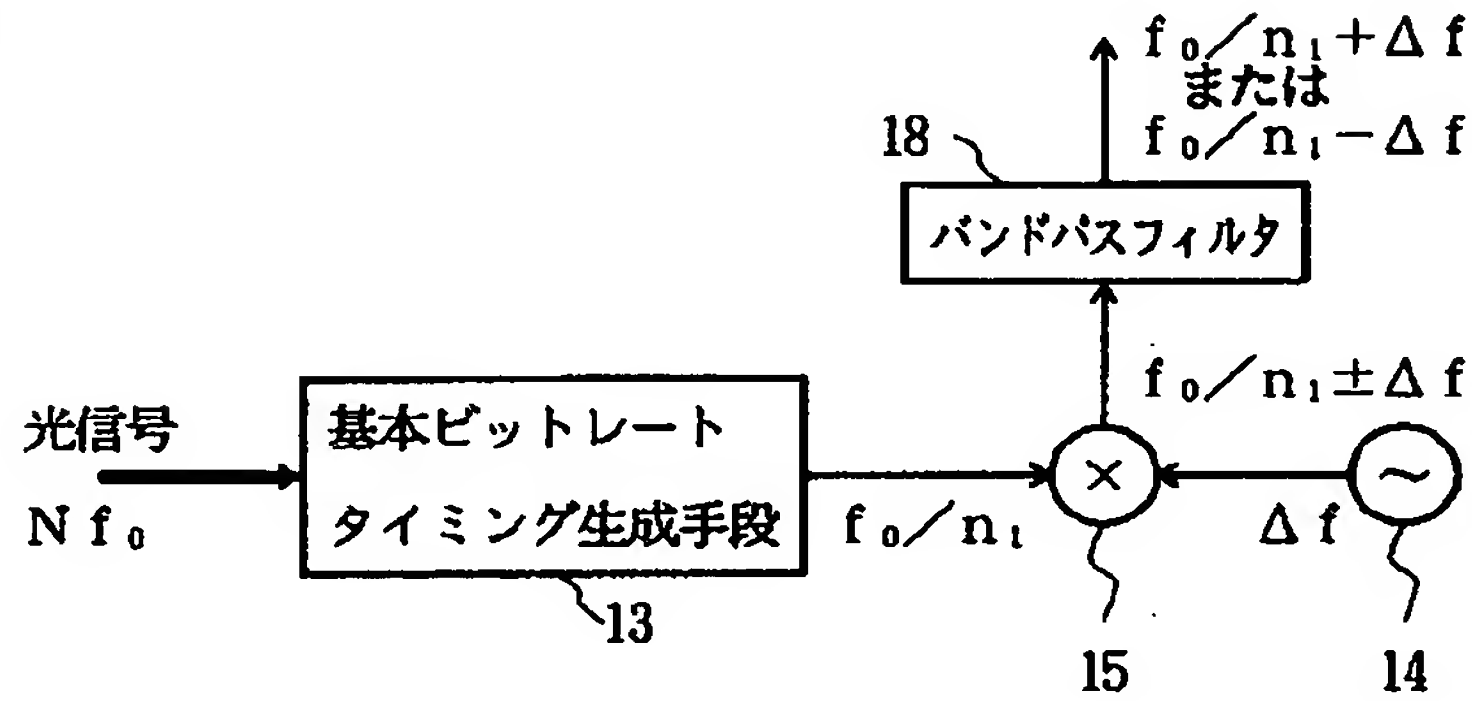
光信号のアイパタンおよび光強度ヒストグラム



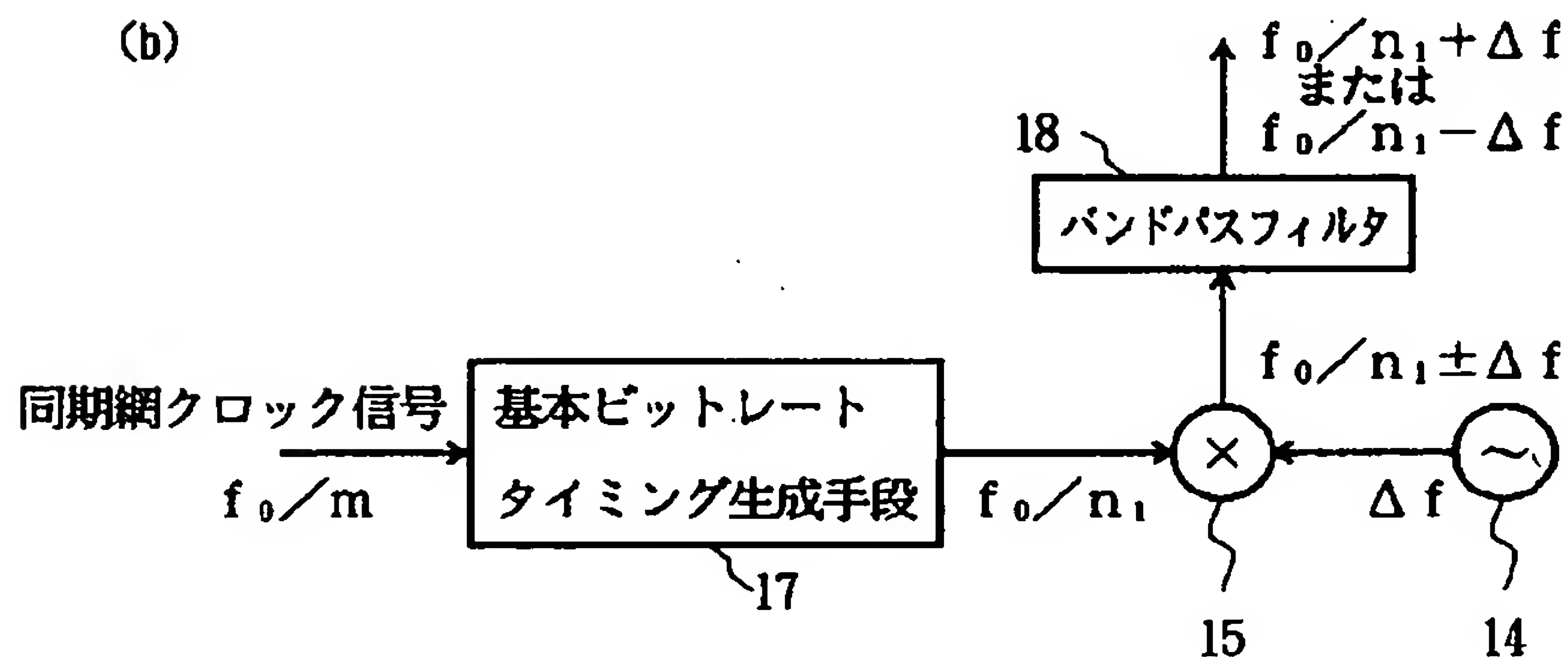
【図９】

タイミングクロック発生手段の構成例

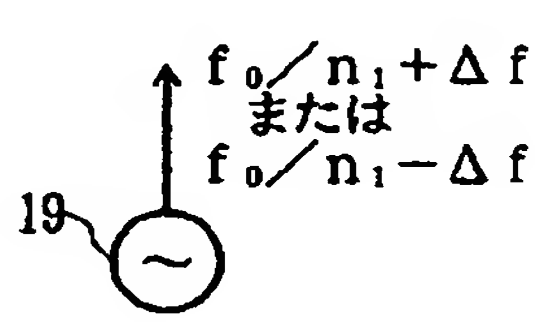
(a)



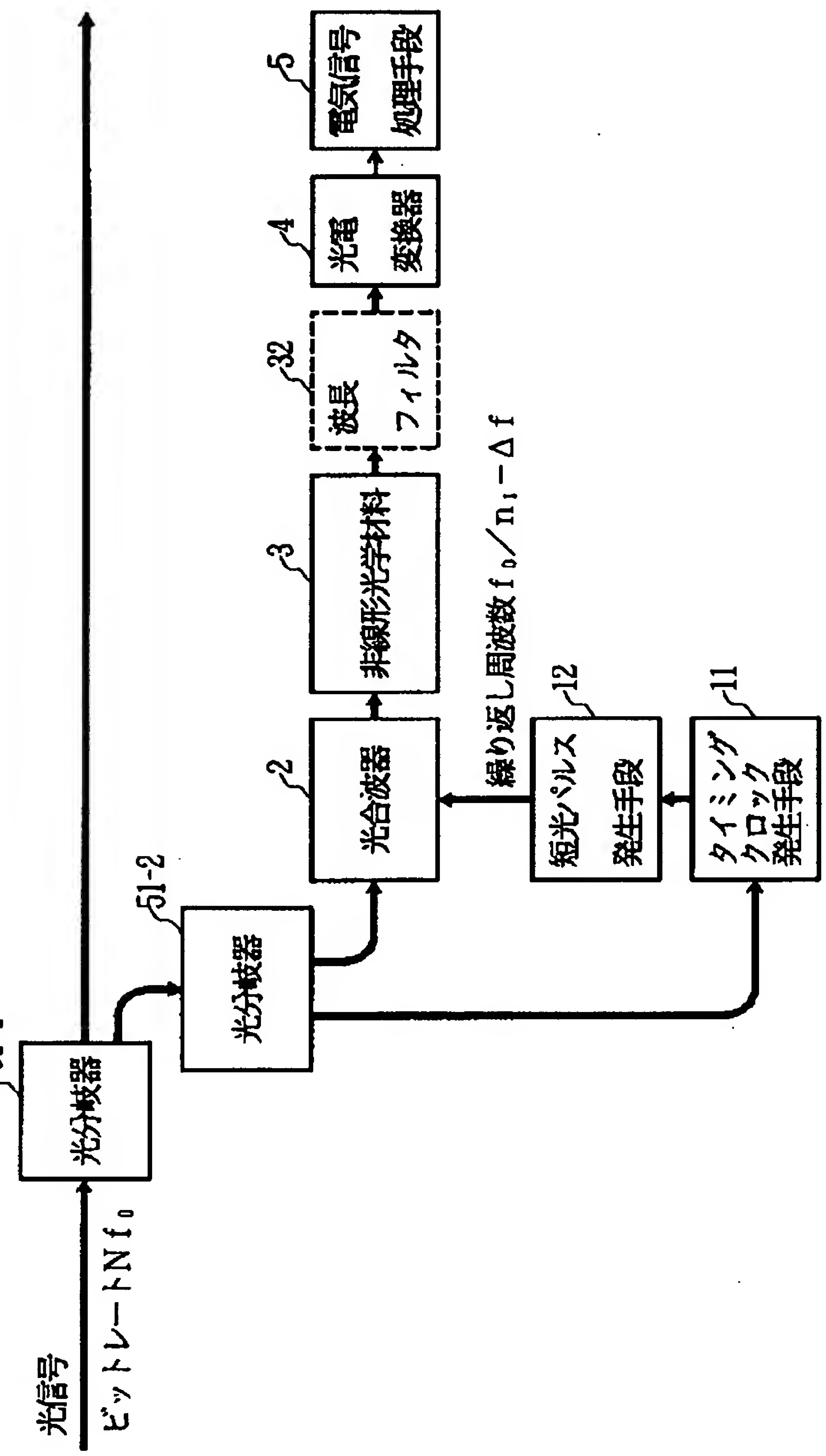
(b)



(c)



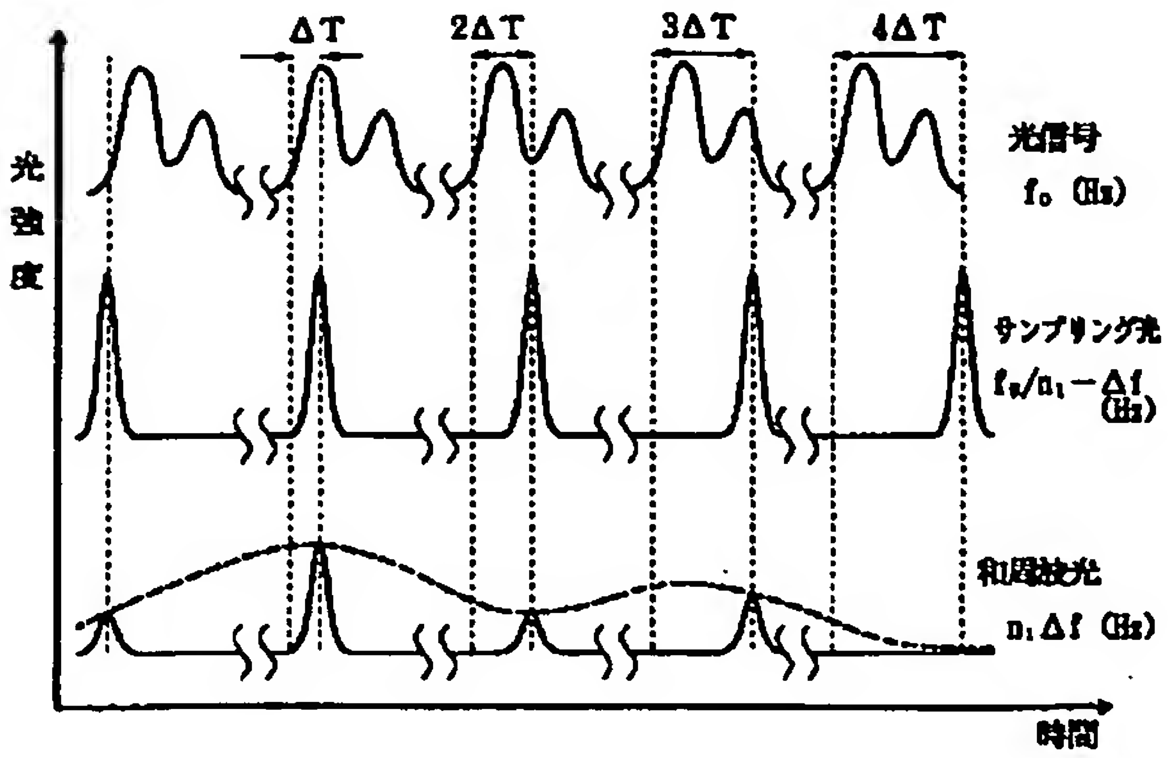
【図８】



本発明の光信号品質モニタの第１の実施形態

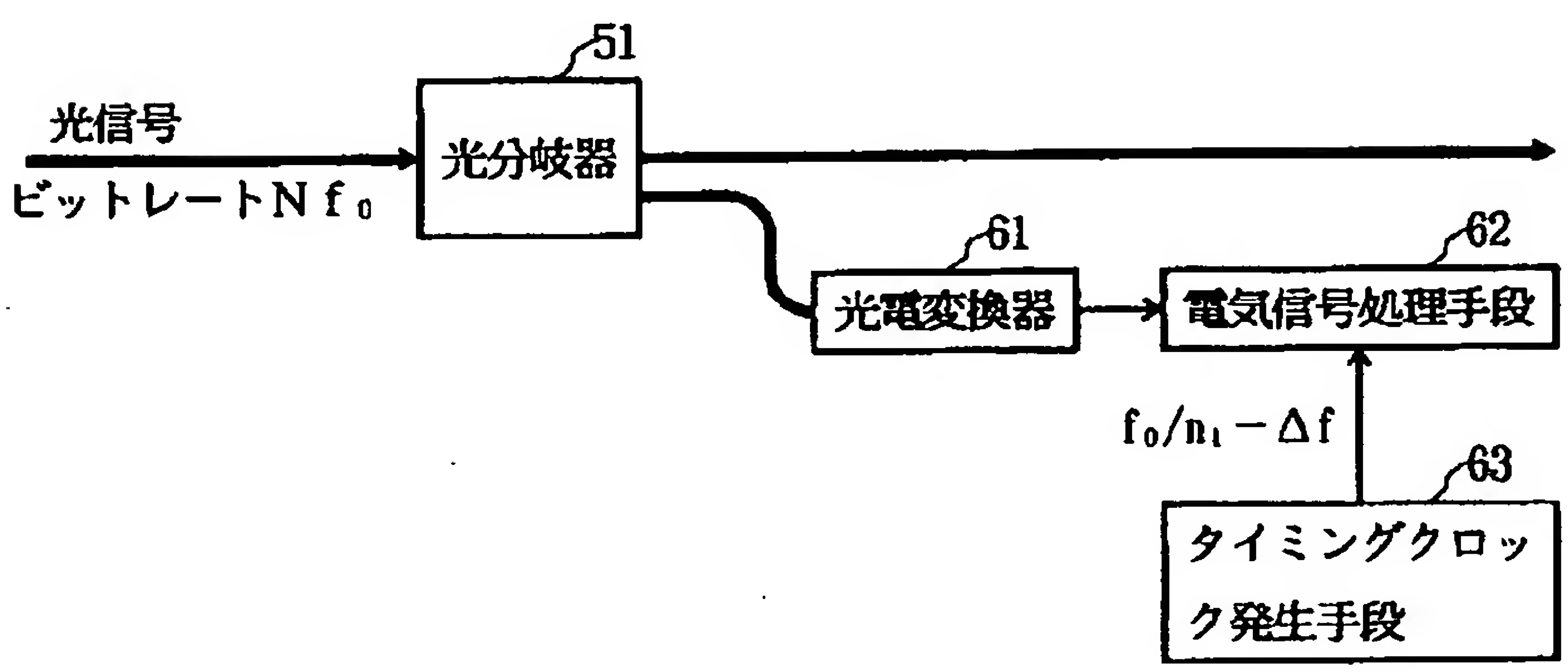
【図１０】

光信号とサンプリング光および発生した和周波光の時間軸上の関係

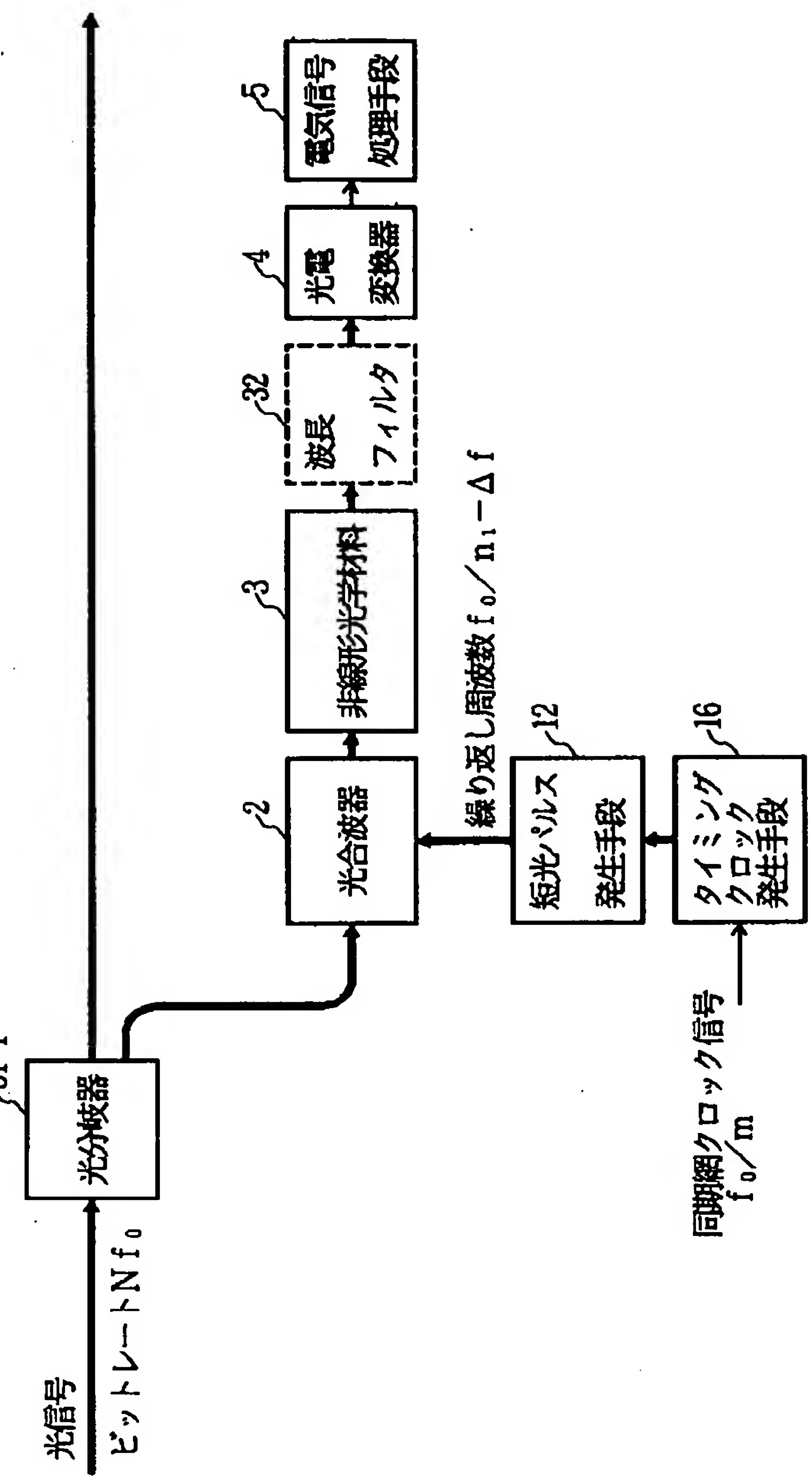


【図１７】

本発明の光信号品質モニタの第８の実施形態



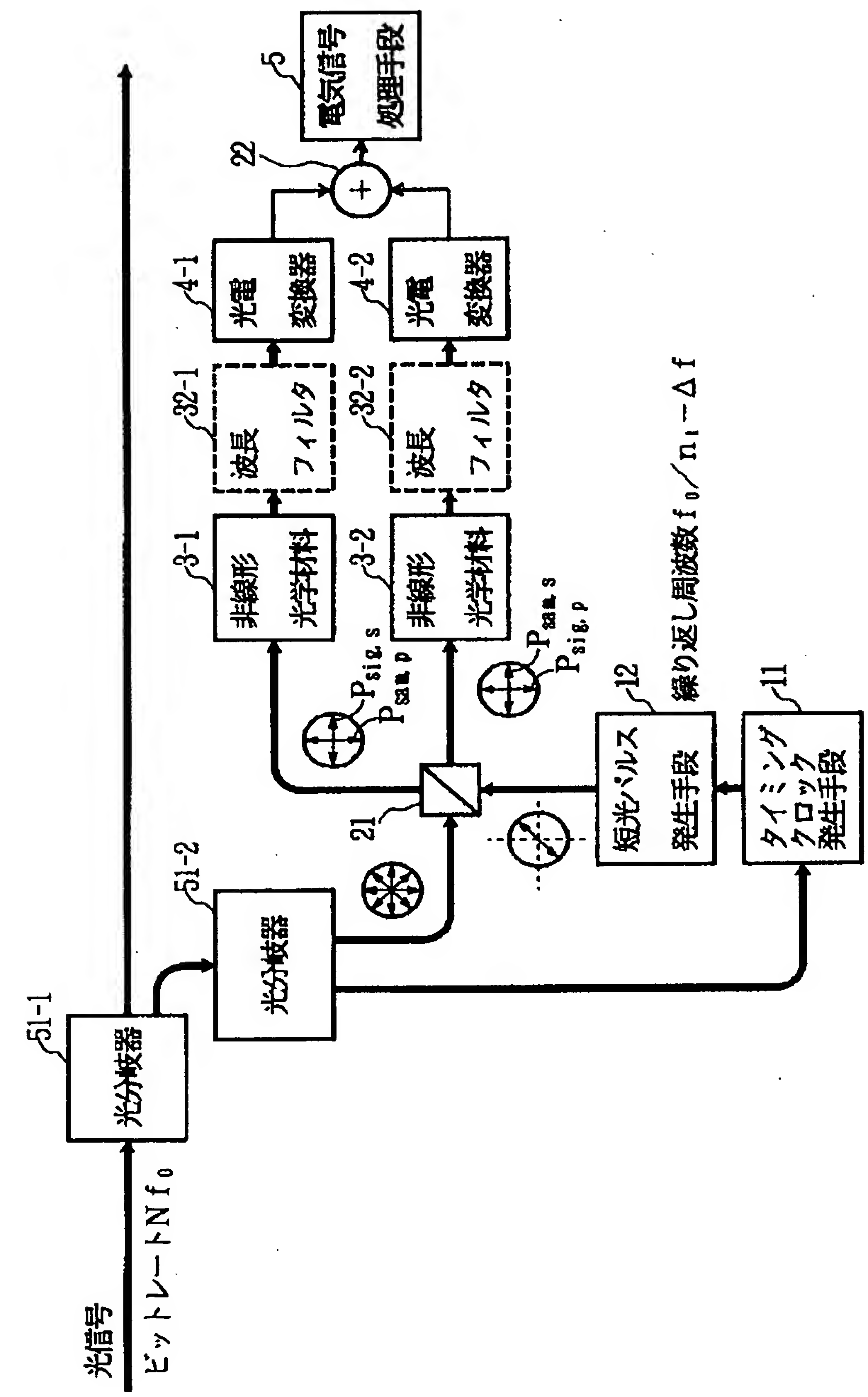
【図１１】



本発明の光信号品質モニタの第２の実施形態

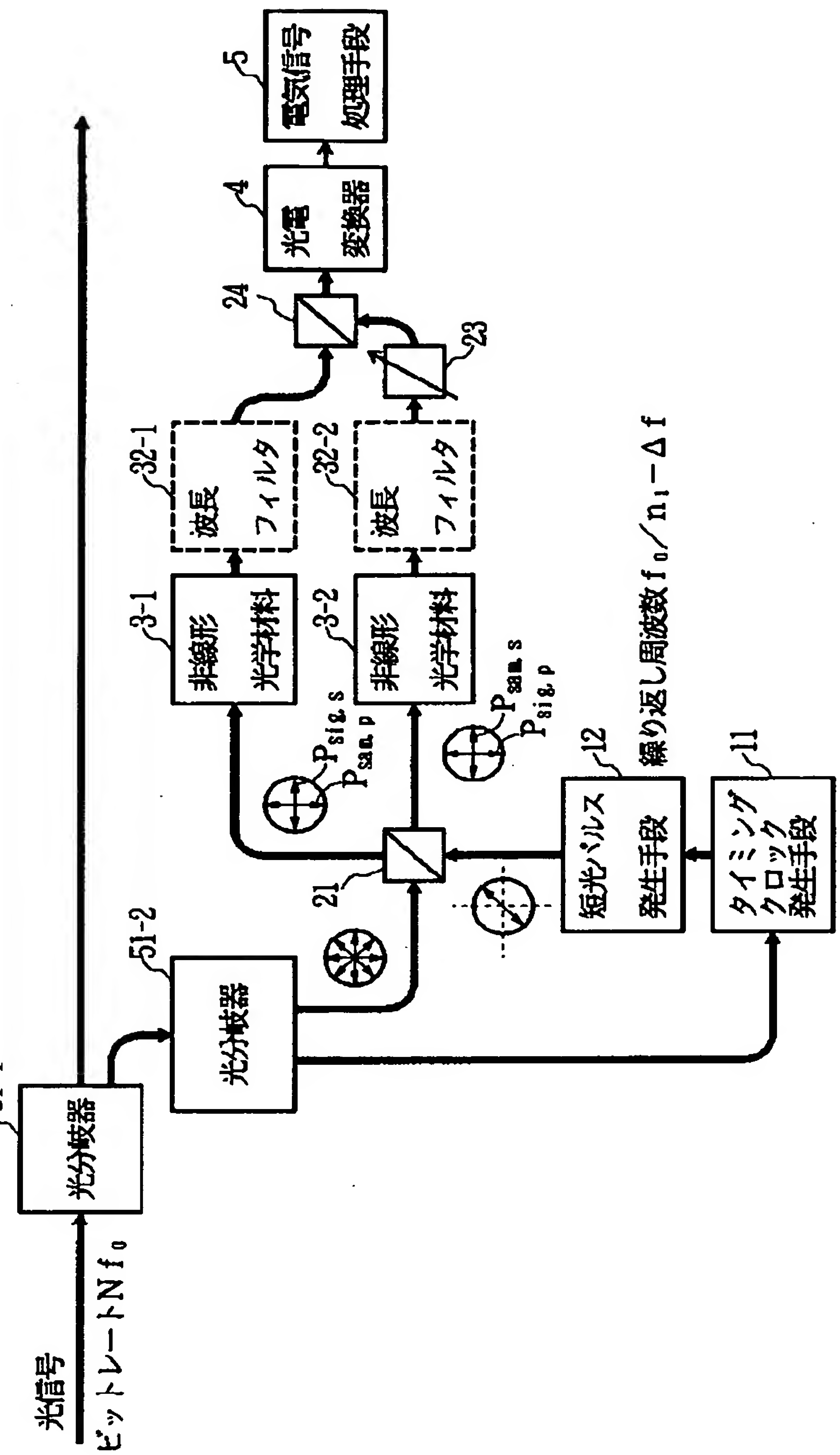
【図12】

本発明の光信号品質モニタの第3の実施形態



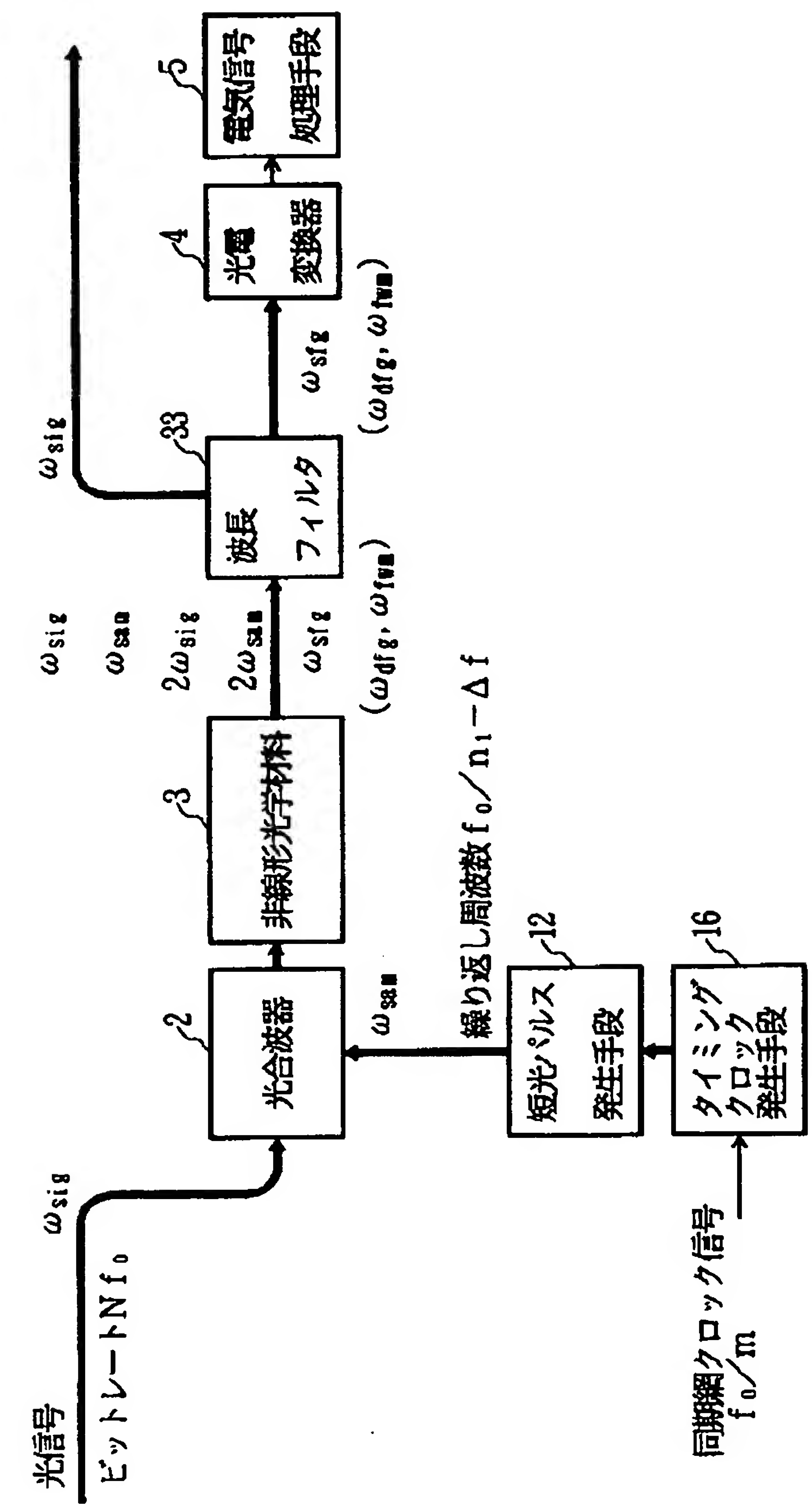
【図１３】

本発明の光信号品質モニタの第４の実施形態

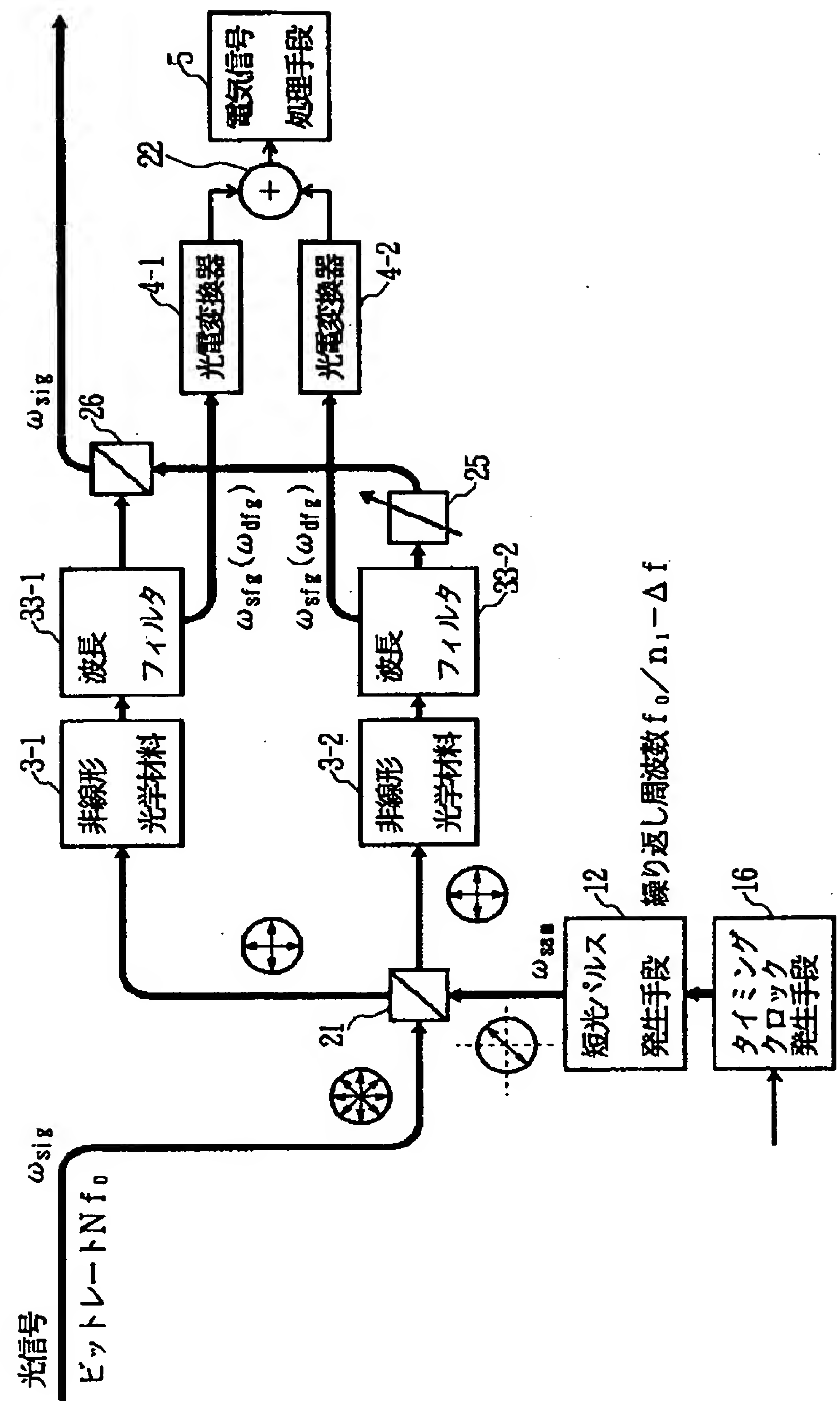


【図１４】

本発明の光信号品質モニタの第５の実施形態



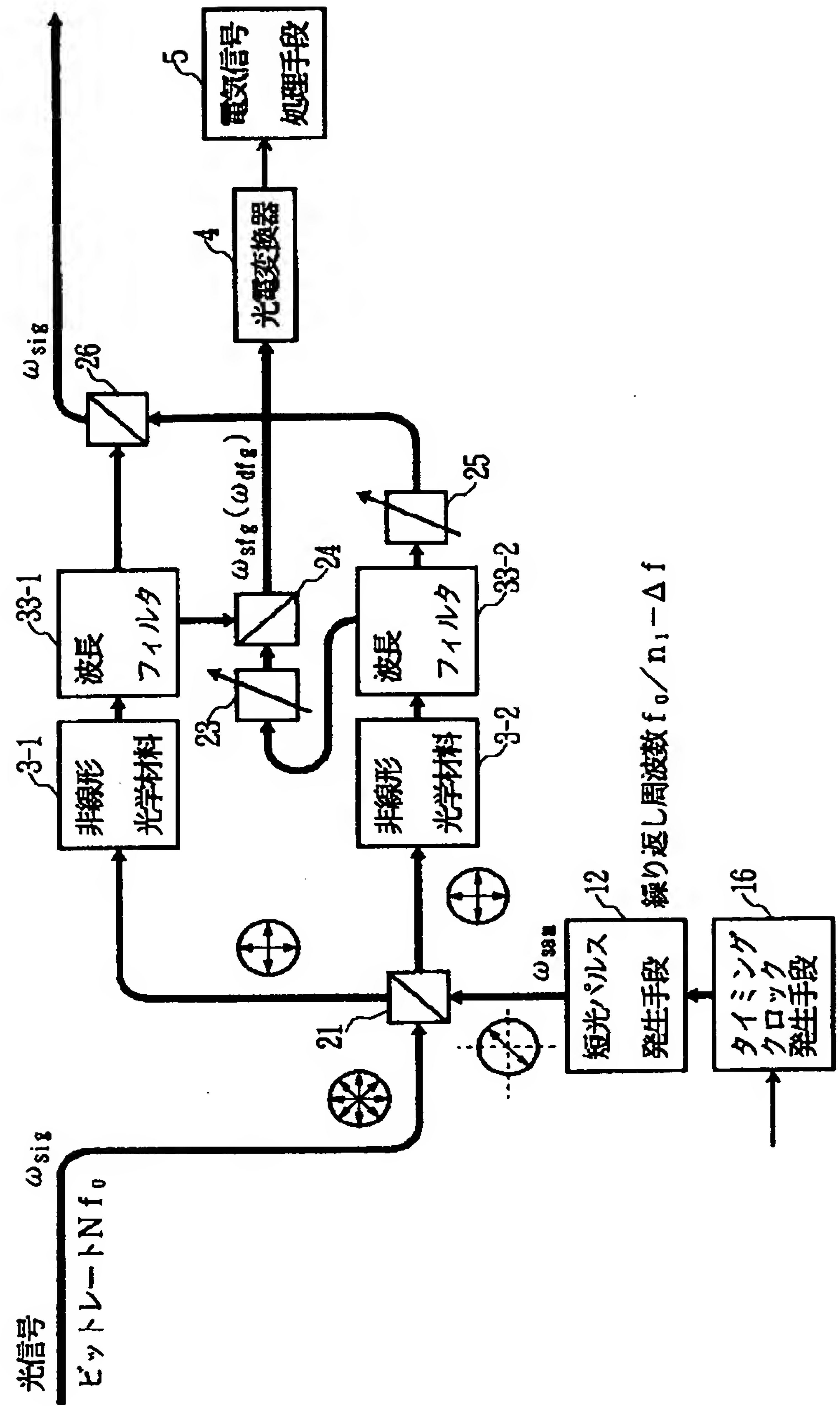
【図１５】



本発明の光信号品質モニタの第６の実施形態

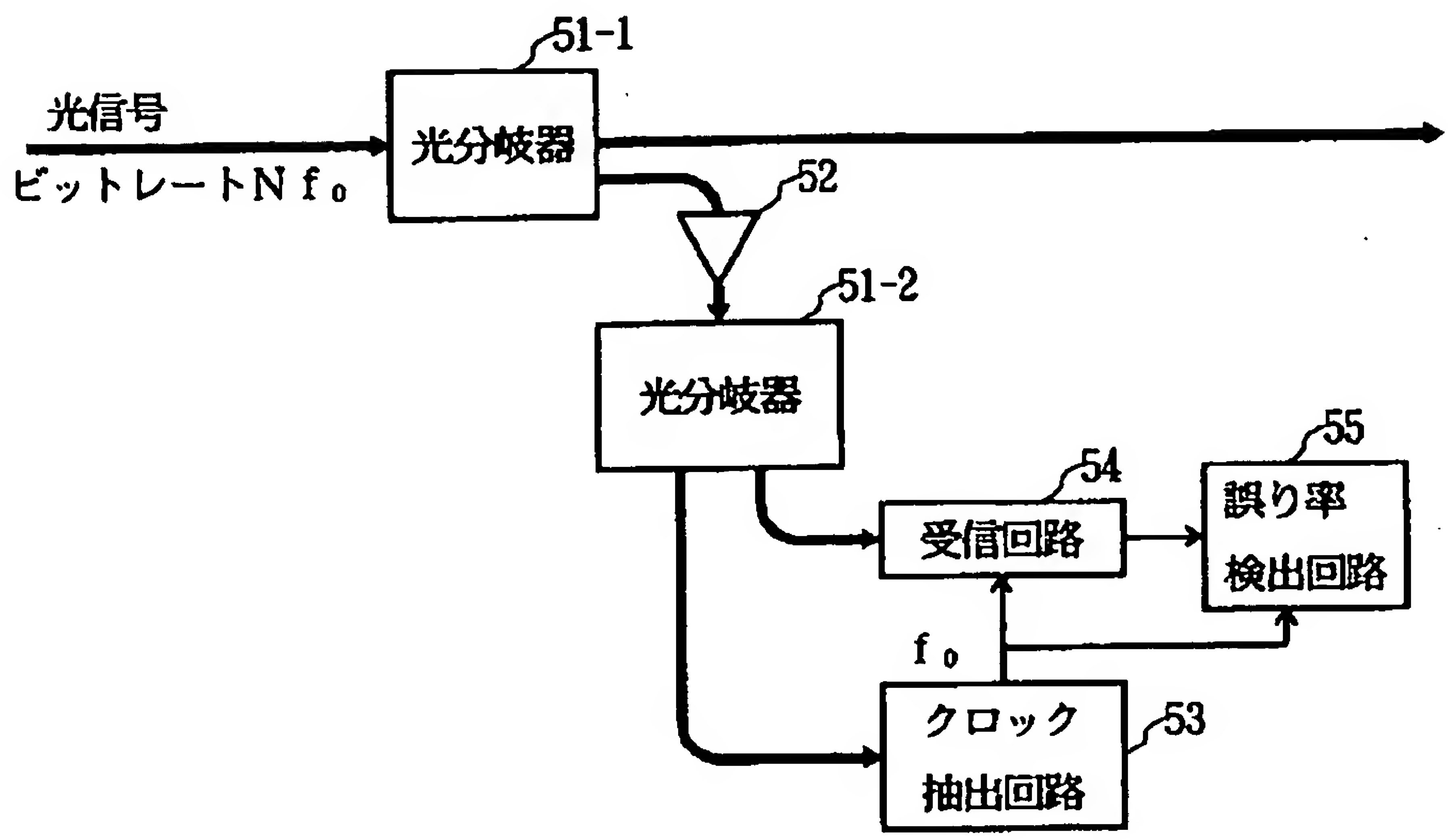
【図１６】

本発明の光信号品質モニタの第７の実施形態



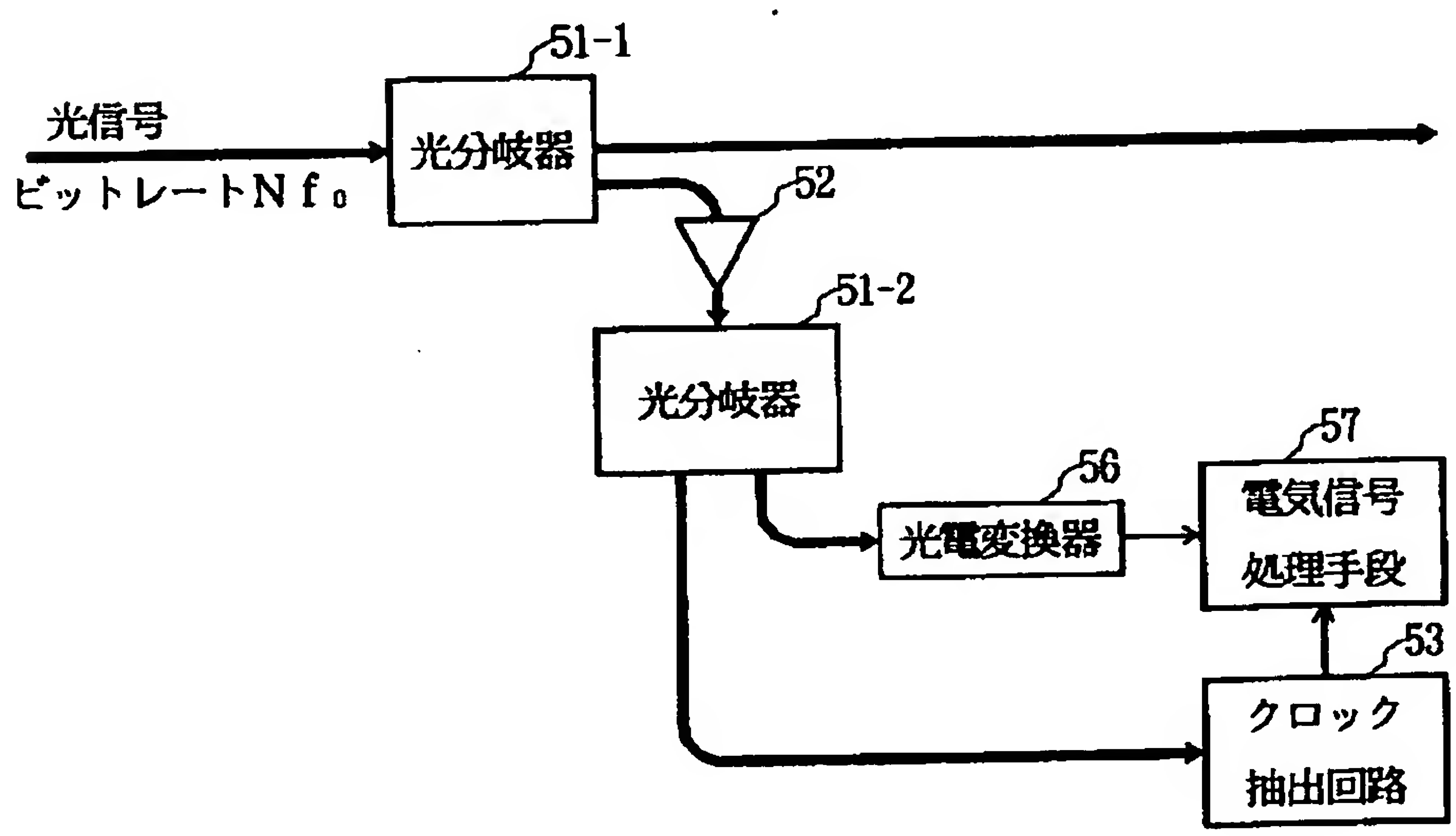
【図18】

従来の誤り率測定系の構成例



【図20】

光信号のアイパタンの測定系



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CLAIMS

[Claim(s)]
[Claim 1] Basic clock frequency f0 Slightly different repeat frequency f0-/n1-deltaf from 1 for an integer of (Hz) (Hz) Or f0/n1+deltaf (Hz) A sampling light pulse generating means to generate the sampling light pulse train which it has, Said basic clock frequency f0 Bit rate N-f0 (bit/s) of the integral multiple of (Hz) The lightwave signal which it has, Said lightwave signal it was multiplexed [lightwave signal] with the optical multiplexing machine which multiplexs said sampling light pulse train, and said optical multiplexing vessel, and said sampling light pulse train are inputted. The non-linear optical material which samples said lightwave signal in said sampling light pulse train by outputting the cross-correlation lightwave signal produced according to a nonlinear optical effect, The histogram of optical reinforcement is measured from the optical/electrical converter which changes said cross-correlation lightwave signal into a cross-correlation electrical signal, and said cross-correlation electrical signal. the sampling point which constitutes the histogram on the strength [optical] to "level 1", and "level 0" -- with the difference of the average-value level within between each existing mean time "level 1" and "level 0" -- the lightwave signal quality monitor characterized by having an electrical signal processing means to ask for the ratio of the sum of the standard deviation value within each mean time concerned as a signal-to-noise-ratio multiplier, and to inspect the quality of said lightwave signal.
[Claim 2] Basic clock frequency f0 The bit rate N of the integral multiple of (Hz), and f0 (bit/s) The optical/electrical converter which changes into an electrical signal the lightwave signal which it has, Said basic clock frequency f0 Slightly different repeat frequency f0-/n1-deltaf from 1 for an integer of (Hz) (Hz) Or f0/n1+deltaf (Hz) A timing clock generating means to generate a timing clock, Sample the level of said electrical signal by said timing clock, and the histogram is measured. the sampling point which constitutes the histogram to "level 1", and "level 0" -- with the difference of the average-value level within between each existing mean time "level 1" and "level 0" -- the lightwave signal quality monitor characterized by having an electrical signal processing means to ask for the ratio of the sum of the standard deviation value within each mean time concerned as a signal-to-noise-ratio multiplier, and to inspect the quality of said lightwave signal.
[Claim 3] In a lightwave signal quality monitor according to claim 1 or 2 an electrical signal processing means A point group higher than the threshold level beforehand defined among the sampling points which constitute a histogram is made into "level 1." moreover, a point group lower than the threshold level defined separately -- "level 0" -- carrying out -- "level 1" and "level 0" -- the difference mu of the average-value level within between each existing mean time, "level 1", and "level 0" -- ratio Q=mu/(sigma1+sigma0) of the sum (sigma1+sigma0) of the standard deviation value within each mean time concerned
The lightwave signal quality monitor characterized by being the configuration for which it asks as a signal-to-noise-ratio multiplier.
[Claim 4] In a lightwave signal quality monitor according to claim 3 an electrical signal processing means It asks for the histogram of level from the sampling point beforehand measured in specific time amount. It integrates with the number of sampling points from the level maximum of this histogram. The total number of sampling points Ntotal, When the duty ratio (ratio of pulse width and a time slot) of a lightwave signal is set to D and a mark rate (probability of occurrence of the "level 1" in digital transmission) is set to M It is mean value mum about the level when becoming equal to the number Nmiddle of sampling points which can

be found in Nmiddle=NtotalxDxM. It carries out. the level to which the number of sampling points serves as peak value from a level minimum value side in said histogram at the beginning -- the average mu 0 of "level 0" It carries out. ** -- "Level 0" and threshold level muth0 of "level 1", and muth1 Lightwave signal quality monitor characterized by being referred to as muth0 =2alphamum+(1-2alpha) mu0microth1 =2(1-alpha) mum-(1-2alpha) mu00.1 <alpha< 0.4.

[Claim 5] In a lightwave signal quality monitor according to claim 1 or 2 an electrical signal processing means The point group in a high level field is made into "level 1" between two fields beforehand appointed among the sampling points which constitute a histogram. the point group in a low level field -- "level 0" -- carrying out -- "level 1" and "level 0" -- difference mu' of the average-value level within between each existing mean time, and "level 1" and "level 0" -- ratio Q=mu'/(sigma1+sigma0) of the sum (sigma1+sigma0) of the standard deviation value within each mean time concerned

The lightwave signal quality monitor characterized by being the configuration for which it asks as a signal-to-noise-ratio multiplier.

[Claim 6] In a lightwave signal quality monitor according to claim 5 an electrical signal processing means It asks for the histogram of level from the sampling point beforehand measured in specific time amount. It integrates with the number of sampling points from the level maximum of this histogram. The total number of sampling points Ntotal, When the duty ratio (ratio of pulse width and a time slot) of a lightwave signal is set to D and a mark rate (probability of occurrence of the "level 1" in digital transmission) is set to M It is mean value mum about the level when becoming equal to the number Nmiddle of sampling points which can be found in Nmiddle=NtotalxDxM. It carries out. the level to which the number of sampling points serves as peak value from a level minimum value side in said histogram at the beginning -- the average mu 0 of "level 0" It carries out. ** -- "Level 0" and threshold level muth0 of "level 1", and muth1 It is referred to as muth0 =2alphamum+(1-2alpha) mu0microth1 =2(1-alpha) mum-(1-2alpha) mu00.1 <alpha< 0.4. They are mumax and mumin about the maximum and the minimum value of level in the sampling point measured in said specific time amount, respectively. It carries out. It is mumin about the range of "level 0". It is muth0 above. It considers as the following and is muth1 about the range of "level 1". It is mumax above. Lightwave signal quality monitor characterized by considering as the following.

[Claim 7] It is the lightwave signal quality monitor characterized by being the sum cycle light which generated the cross-correlation lightwave signal according to the nonlinear optical effect in the lightwave signal quality monitor according to claim 1, difference cycle light, or 4 light-wave mixing light.

[Claim 8] In a lightwave signal quality monitor according to claim 1 a sampling light pulse generating means Frequency f0-/n1-deltaf which adjusted offset frequency deltaf (Hz) from 1 for an integer of the basic clock frequency f0 of the lightwave signal which branched from the transmission line (Hz) (Hz) or f0/n1+deltaf A timing clock generating means to generate the timing clock of (Hz), Said timing clock is used and it is repeat frequency f0-/n1-deltaf. (Hz) or f0/n1+deltaf By (Hz) The lightwave signal quality monitor characterized by having a short light pulse generating means to generate a sampling light pulse train with pulse width narrower enough than the time slot of a lightwave signal.

[Claim 9] In a lightwave signal quality monitor according to claim 2 or 8 a timing clock generating means It is the basic clock frequency f0 of the clock signal extracted from the lightwave signal which branched from the transmission line (Hz) f0 / n1 (Hz) The counting-down circuit which carries out dividing, n1, and n2 When it considers as the natural number and deltaT is made into sampling step time deltaf=f0 (n1+f0deltaT) / n1 (n1+n2+f0deltaT)

The lightwave-signal quality monitor characterized by to have the band pass filter which outputs only the frequency component of f0-/n1-deltaf (Hz) or f0/n1+deltaf (Hz) from the mixer which mixes the oscillator out of which it comes, and which is oscillated by OSESETTO frequency deltaf expressed, and said clock signal by which dividing was carried out and output of said oscillator, and generates the timing clock of frequency f0/n1**deltaf (Hz), and said mixer output.

[Claim 10] In a lightwave signal quality monitor according to claim 1 a sampling light pulse generating means Basic clock frequency f0 (Hz) Clock frequency f0 / m of 1 for an integer (Hz) The synchronous-network clock signal which it has is inputted. Frequency f0-/n1-deltaf which adjusted offset frequency deltaf (Hz) from 1 for an integer of a basic clock frequency (Hz) or f0/n1+deltaf A timing clock generating means to generate the timing clock of (Hz), Said timing clock is used and it is repeat frequency f0-/n1-deltaf. (Hz) or f0/n1+deltaf By (Hz) The lightwave signal quality monitor characterized by having a short light pulse generating means to generate a sampling light pulse train with pulse width narrower enough than the time

slot of a lightwave signal.
[Claim 11] In a lightwave signal quality monitor according to claim 2 or 10 a timing clock generating means clock frequency f0 / m (Hz) a synchronous-network clock signal -- the frequency f0 of 1 for an integer of the basic clock frequency f0 (Hz) / n1 (Hz) With multiplying, the multiplier which carries out dividing, or a counting-down circuit n1 and n2 When it considers as the natural number and deltaT is made into sampling step time, it is deltaf=f0 (n1+f0deltaT) / n1 (n1+n2+f0deltaT).
The mixer which mixes the oscillator out of which it comes, and which is oscillated by OSESETTO frequency deltaf expressed, said multiplying or clock signal by which dividing was carried out, and the output of said oscillator, and generates the timing clock of frequency f0/n1**deltaf (Hz), The lightwave signal quality monitor characterized by having the band pass filter which outputs only the frequency component of f0-/n1-deltaf (Hz) or f0/n1+deltaf (Hz) from said mixer output.
[Claim 12] In a lightwave signal quality monitor given in either of claims 2, 8, and 10 a timing clock generating means the frequency f0 of 1 for an integer of the basic clock frequency f0 (Hz) / n1 (Hz) from -- n1 and n2 the time of considering as the natural number and making deltaT into sampling step time -- deltaf=f0 (n1+f0deltaT) / n1 (n1+n2+f0deltaT)
Frequency f0-/n1-deltaf which came out and adjusted OSESETTO frequency deltaf expressed (Hz) Or lightwave signal quality monitor characterized by having the oscillator oscillated by f0/n1+deltaf (Hz).
[Claim 13] The lightwave signal quality monitor characterized by being the configuration which multiplexs the lightwave signal which was equipped with the optical turnout which branches in a part of lightwave signal from a transmission line in the lightwave signal quality monitor according to claim 8 or 10, and branched by said optical turnout, and the sampling light pulse train outputted from the sampling light pulse generating means with an optical multiplexing vessel.
[Claim 14] In a lightwave signal quality monitor according to claim 13 an optical multiplexing machine Two polarization components which intersect perpendicularly a lightwave signal and a sampling light pulse train, respectively (Psig.p, Psig.s), It separates into (Psam.p and Psam.s). Further The components (Psig.p, Psam.s) which intersect perpendicularly mutually As opposed to two polarization composition light which is polarization separation composition means to carry out polarization composition of (Psig.s and the Psam.p), and to output to two output ports, and is outputted from said polarization separation composition means The lightwave signal quality monitor characterized by having the adder circuit which is made to generate a cross-correlation lightwave signal, respectively, adds two non-linear optical materials and optical/electrical converter which are further changed into a cross-correlation electrical signal, and said two cross-correlation electrical signals, and is sent out to an electrical signal processing means.
[Claim 15] In a lightwave signal quality monitor according to claim 13 an optical multiplexing machine Two polarization components which intersect perpendicularly a lightwave signal and a sampling light pulse train, respectively (Psig.p, Psig.s), It separates into (Psam.p and Psam.s). Further The components (Psig.p, Psam.s) which intersect perpendicularly mutually As opposed to two polarization composition light which is polarization separation composition means to carry out polarization composition of (Psig.s and the Psam.p), and to output to two output ports, and is outputted from said polarization separation composition means The lightwave signal quality monitor characterized by having a polarization composition means to double the timing of said two cross-correlation lightwave signals with two non-linear optical materials made to generate a cross-correlation lightwave signal, respectively, to carry out polarization composition, and to send out to an optical/electrical converter.
[Claim 16] In a lightwave signal quality monitor according to claim 8 or 10, an optical multiplexing machine and a non-linear optical material are inserted in a transmission line. Multiplex with an optical multiplexing vessel and the lightwave signal from a transmission line and the sampling light pulse train outputted from the sampling light pulse generating means are inputted into a non-linear optical material. The lightwave signal quality monitor characterized by having a wavelength separation means to be inserted in a transmission line, to separate the lightwave signal and cross-correlation lightwave signal which are outputted from said non-linear optical material, to send out a lightwave signal to a transmission line, and to send out a cross-correlation lightwave signal to an optical/electrical converter.
[Claim 17] In a lightwave signal quality monitor according to claim 16 an optical multiplexing machine Two polarization components which intersect perpendicularly a lightwave signal and a sampling light pulse train, respectively (Psig.p, Psig.s), It separates into (Psam.p and Psam.s). Further The components (Psig.p, Psam.s) which intersect perpendicularly mutually As opposed to two polarization composition light which is

polarization separation composition means to carry out polarization composition of (Psig.s and the Psam.p), and to output to two output ports, and is outputted from said polarization separation composition means Two non-linear optical materials and the wavelength separation means of generating a cross-correlation lightwave signal, respectively and separating a lightwave signal and a cross-correlation lightwave signal further, A polarization composition means to double the timing of said two lightwave signals, to carry out polarization composition, and to send out to a transmission line, The lightwave signal quality monitor characterized by having two optical/electrical converters which change said two cross-correlation lightwave signals into a cross-correlation electrical signal, and the adder circuit which adds said two cross-correlation electrical signals, and is sent out to an electrical signal processing means.
[Claim 18] In a lightwave signal quality monitor according to claim 16 an optical multiplexing machine Two polarization components which intersect perpendicularly a lightwave signal and a sampling light pulse train, respectively (Psig.p, Psig.s), It separates into (Psam.p and Psam.s). Further The components (Psig.p, Psam.s) which intersect perpendicularly mutually As opposed to two polarization composition light which is polarization separation composition means to carry out polarization composition of (Psig.s and the Psam.p), and to output to two output ports, and is outputted from said polarization separation composition means Two non-linear optical materials and the wavelength separation means of generating a cross-correlation lightwave signal, respectively and separating a lightwave signal and a cross-correlation lightwave signal further, The lightwave signal quality monitor characterized by having the 1st polarization composition means which doubles the timing of said two lightwave signals and carries out polarization composition, and which is sent out to a transmission line, and the 2nd polarization composition means which doubles the timing of said two cross-correlation lightwave signals, and carries out polarization composition, and which is sent out to an optical/electrical converter.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the lightwave signal quality monitor which carries out the monitor of the signal-to-noise ratio of a lightwave signal in the optical-fiber-transmission network where the digital lightwave signal of a different bit rate is transmitted.
[0002]
[Description of the Prior Art] In SDH (Synchronous Digital Hierarchy) which became global unification network ladder structure in the 1990s, identification and the change seizing signal of the failure section have been acquired by carrying out parity check called bit interleave parity between the multiplexing terminal offices (BIP-Nx24) between repeaters (BIP-8), respectively. Here, N is N of STM-N showing the number of multiplexing, and is 156 Mbit/s. The ladder of the integral multiple is expressed as STM-N on the basis of STM-1. In addition, N= 1, and 4, 16 and 64 are recognized internationally. BIP-M means the parity check in every M bits, and a M-bit check bit is obtained. Parity check with parallel M bits of the signal in a frame is performed by the transmitting side, the check bit is stored in the following frame, and it transmits with the main signal. In a receiving side, same parity check is conducted and a transmission error is detected by collating with the check bit stored in the predetermined location of degree frame.
[0003] Drawing 18 shows the example of a configuration of the conventional error rate system of measurement. In drawing, a part of lightwave signal from a transmission line branches by the optical turnout 51-1, it is amplified with a light amplifier 52, and dichotomizes by the optical turnout 51-2 further. While branching by the optical turnout 51-2, it is inputted into the clock extract circuit 53, and a lightwave signal is the bit rate Nf0 of a lightwave signal. Clock f0 which responded It is extracted. The lightwave signal of another side which branched by the optical turnout 51-2 is inputted into a receiving circuit 54, and is inputted into the error rate detector 55 where the output consists of a frame detector, a parity check circuit, and a correlation circuit further. A receiving circuit 54 and the error rate detector 55 are the clock f0 extracted in the clock extract circuit 53. It responds and operates and the error rate of a lightwave signal is measured. In addition, the thing of the configuration according to the bit rate of a lightwave signal is required for the clock extract circuit 53, a receiving circuit 54, and the error rate detector 55. That is, in order to perform error rate detection corresponding to two or more bit rates, it is necessary to prepare the circuit corresponding to each bit rate, and cannot respond in a single circuit.
[0004] By the way, in order to evaluate a transmission system, the method of measuring the error rate of a signal directly is common. However, by this approach, there was a problem to which the measuring time becomes this thing for a long time in the case of a very low error rate, and working efficiency becomes low.

[0005] Then, the method of presuming the error rate in the optimal operating point from the inclination of the error rate acquired when changing the threshold of a discrimination circuit was devised (reference 1:N.S.Bergano et al., "Margin Measurement in Optical Amplifier Systems", IEEE Photonics Technology Letters, vol.5, no.3, pp.304-306). . The eye pattern and the histogram on the strength [optical] of a lightwave signal are shown in drawing 19 . When eye opening of this eye pattern becomes max (discernment point), by changing the threshold of a discrimination circuit, "yes" or "1" level in binary transmission, and a "low" or "0" level are distinguished, and the rate of the error at that time is measured.
[0006] The system of measurement by the clock extract circuit 53 as shown in drawing 20 , the

optical/electrical converter 56, and the electrical signal processing means 57 is constituted actually, and it is considering as the assessment index in quest of the Q value which is equivalent to a signal-to-noise ratio from the threshold dependency of an error rate. That is, a part of lightwave signal from a transmission line is changed into an electrical signal with an optical/electrical converter 56, the clock extracted in this electrical signal and the clock extract circuit 53 is inputted into an electrical signal processing means 57 like a sampling oscilloscope, and an eye pattern like drawing 19 and a histogram on the strength [optical] are obtained.
[0007] Time amount t0 from which eye opening of this eye pattern serves as max Set and signal amplitude (for example, electrical-potential-difference value) is set to mu (t0). When the standard deviation of the noise of "yes" or "1" level in binary transmission is set to sigma0 (t0), Q (t0) value the standard deviation of the noise of sigma1 (t0), "low", or "0" level Q(t0) =mu(t0)/(sigma1(t0)+sigma0 (t0)) -- It defines as (1). On the other hand, when the noise amplitude distribution of a gauss mold is assumed, in the low field of an error rate, error rate P and Q value are P=(1/(Q(2pi) 1/2)) exp (-Q2/2). -- There is relation as shown in (2). Therefore, if Q value can be measured, a transmission-line error rate can be presumed.
[0008]
[Problem(s) to be Solved by the Invention] However, since the wave was sampled after the conventional Q value system of measurement changed the lightwave signal into the electrical signal, as shown in drawing 20 , and Q value was calculated, the bit rate of the lightwave signal which can respond with the band and processing speed of an optical/electrical converter or an electrical signal processing circuit was restricted to 40 Gbit/s extent.
[0009] Moreover, since the Q value in the event of eye opening serving as max was measured, it was not able to respond to the digital lightwave signal of a different bit rate. Moreover, since the conventional Q value system of measurement needs to branch the lightwave signal for monitors from a transmission line, loss by branching arises in the lightwave signal on a transmission line, and it has become the factor which degrades a signal-to-noise ratio.
[0010] This invention aims at offering the lightwave signal quality monitor which cannot be based on the bit rate of a measuring beam-ed signal, but can carry out the monitor of the signal-to-noise ratio in a single circuit in the optical-fiber-transmission network where the digital lightwave signal of a different bit rate is transmitted.
[0011] Moreover, this invention is dozens Gbit/s. It aims at offering the lightwave signal quality monitor which can respond also to the lightwave signal of the above bit rate. Moreover, this invention aims at offering the lightwave signal quality monitor which can reduce the effect which it has on the signal-to-noise ratio of the lightwave signal of a transmission line.
[0012]
[Means for Solving the Problem] A lightwave signal quality monitor according to claim 1 is a configuration which carries out the monitor of the signal-to-noise ratio with an optical means from the statistics processing value of the amplitude value of the histogram on the strength [optical] by the bit rate of a lightwave signal to a sampling point. Hereafter, the basic configuration is explained.
[0013] Drawing 1 shows the basic configuration of a lightwave signal quality monitor according to claim 1. the lightwave signal inputted from a transmission line in drawing -- optical frequency omegasig -- basic clock frequency f0 It has bit rate N-f0 (bit/s) (N= 1, 2, --) of the integral multiple of (Hz). The sampling light pulse generating means 1 Optical frequency omegasam, basic clock frequency f0 1 for an integer of (Hz) and offset frequency deltaf (Hz) were adjusted -- repeating -- frequency f0-/n1-deltaf (Hz) (n (or f0/n1+deltaf (Hz)) 1 = 1, 2, --) Pulse width deltatau generates a sampling light pulse narrower (deltatau<<1/Nf0) enough than the time slot of a lightwave signal. The optical multiplexing machine 2 multiplexs and inputs a lightwave signal and a sampling light pulse into a non-linear optical material 3.
[0014] A non-linear optical material 3 is sum cycle light generating (SFG:Sum Frequency Generation) (reference 2: Takayoshi others) which is one of the secondary nonlinear optical effects. "The ultra high-speed light wave form measuring method by the optical sampling using sum cycle light generating", The Institute of Electronics, Information and Communication Engineers paper magazine, B-I, vol.J75-B-I, no.5, pp.372-380, 1992 and difference cycle light generating (DFG:Defference Frequency Generation), 4 light-wave mixing (FWM:Four Wave Mixing) (reference 3-.A.Andrekson, Electron.Lett.27, p.1440, 1991) which is the 3rd nonlinear optical effect is used. A lightwave signal and the cross-correlation lightwave signal of a sampling light pulse are generated.

[0015] Drawing 2 (a), (b), and (c) The relation of the optical frequency in SFG, DFG, and FWM is shown, respectively. SFG is drawing 2 (a). It is optical frequency omegasig so that it may be shown. A lightwave signal and optical frequency omegasam When incidence of the two light waves of a sampling light pulse is carried out to the secondary non-linear optical material, it is the phenomenon which the light of peace optical frequency omegasfg (=omega sam+omega sig) generates. DFG is drawing 2 (b). It is optical frequency omegasig so that it may be shown. A lightwave signal and optical frequency omegasam It is the phenomenon which the light of optical frequency omegadfg (=omega sam-omega sig) of a difference generates from a sampling light pulse.
[0016] Although FWM is a phenomenon which a new light (optical frequency omega4=omega1+omega2-omega3) generally generates from three incident light (optical frequency omega1, omega2, and omega3), in applying to an optical sampling, since a configuration becomes complicated, using three kinds of light uses FWM to which two light waves usually degenerated (omega1=omega2). omega 1 and omega 2 ****** -- the sampling light pulse of optical frequency omegasam -- incidence -- carrying out -- omega 3 ****** -- optical frequency omegasig carrying out incidence of the lightwave signal -- drawing 2 (c) The light of optical frequency omegafwm (=2omega sam-omega sig) is generated so that it may be shown. [namely,]
[0017] Here, the repeat frequency of a sampling light pulse is the basic clock frequency f0 of a lightwave signal. 1/n1 By comparing, since only deltaf is small, the sweep of the sampling light pulse will be carried out, shifting a relative position with a lightwave signal. Consequently, it changes, as a cross-correlation lightwave signal is shown in drawing 1 , and the envelope serves as a wave to which the time-axis of a lightwave signal wave was expanded. By detecting this cross-correlation lightwave signal by the light-receiving system, measurement of the histogram of the optical reinforcement of a high-speed lightwave signal is attained (the above-mentioned reference 2).
[0018] That is, a cross-correlation lightwave signal is changed into an electrical signal with an optical/electrical converter 4, and is inputted into the electrical signal processing means 5. With the electrical signal processing means 5, detection and analysis of the peak value of a cross-correlation electrical signal are performed, and the histogram of optical reinforcement as shown in drawing 3 is measured. And the inside of the sampling point which constitutes the histogram of this optical reinforcement, Threshold level muth1 defined beforehand A high point group is made into "level 1." moreover, threshold level muth0 defined separately a low point group -- "level 0" -- carrying out -- "level 1" and "level 0" -- the average mu 1 within each existing mean time, and mu 0 With Difference mu "level 1" and "level 0" -- ratio Q=mu/(sigma1+sigma0) of the sum (sigma1+sigma0) of the standard deviation value within each mean time concerned -- (3) is calculated as a signal-to-noise-ratio multiplier (claim 3).
[0019] Here, they are above threshold level muth1 and muth0. An example of the approach of determining is explained with reference to drawing 4 (claim 4). First, the electrical signal processing means 5 is mean value mum about the level when asking for the histogram of level from the sampling point beforehand measured in specific time amount, integrating with the number of sampling points from the level maximum of this histogram, and becoming equal to the number Nmiddle of sampling points. It carries out. In addition, the number Nmiddle of sampling points is Nmiddle=NtotalxDxM, when the duty ratio (ratio of pulse width and a time slot) of Ntotal and a lightwave signal is set to D and it sets a mark rate (probability of occurrence of the mark "1" in digital transmission) to M for the total number of sampling points. -- It asks as (4). Moreover, the average mu 1 of "level 1" mu1 =2(micrometer-mu 0)+mu0 -- It is assumed that it is (5).
[0020] next, the level to which the number of sampling points serves as peak value from a level minimum value side in the above-mentioned histogram at the beginning -- the average mu 0 of "level 0" ** -- it carries out. Moreover, "level 0" and threshold level muth0 of "level 1", and muth1 muth0 =mu0+alpha(mu1-mu0) muth1 =mu1-alpha (mu1-mu0) -- It sets up with (6). However, 0< alpha<0.5 It carries out. this -- (6) types if (5) types are substituted -- muth0 =2alphamum+(1-2alpha) mu0microth1 =2(1-alpha) mum-(1-2alpha) mu0 -- (7) is obtained.
[0021] threshold level muth0 determined by the above approach, and muth1 the histogram of the optical reinforcement calculated from total measured value -- the average mu 1 of "level 1" and "level 0", and mu 0 And standard deviation sigma1 and sigma0 It asks and an average signal-to-noise-ratio multiplier (Q value) is calculated from these values.
[0022] This signal-to-noise-ratio multiplier Q is the physical quantity corresponding to 1 to 1 to the signal-to-noise ratio of a lightwave signal. Therefore, the quality of the transmitted lightwave signal can be

inspected by calculating this Q value.
[0023] Drawing 5 is [the average Q value calculated by the above-mentioned approach, and] time amount t0. Relation with the Q value which can be set is shown. drawing -- alpha -- 0.1 If it carries out, in order that the number of sampling points may decrease, dispersion in average Q value becomes large. On the other hand, it is alpha. Since the measured value near the cross point of an eye pattern is contained when it becomes 0.4 or more, the value of average Q value becomes low and the accuracy of measurement worsens. On the other hand, 0.1< alpha<0.4 Since the number of sampling points is also enough and the effect of a cross point can also be avoided, a case is average Q value and time amount t0. Correlation good between the Q value which can be set is acquired. In addition, in this example, a correlation coefficient is carried out and the high value of **** 0.99 is acquired.
[0024] (7) it sets at a ceremony -- 0.1< alpha<0.4 setting up -- each threshold level muth0 and muth1 By determining, the lightwave signal quality of a transmission line can be supervised with a sufficient precision. [therefore,]
[0025] Moreover, the inside of the sampling point which constitutes a histogram as shown in drawing 6 , the inside of two fields appointed beforehand -- the point group in a high level field -- "level 1" -- carrying out -- the point group in a low level field -- "level 0" -- carrying out -- "level 1" and "level 0" -- with difference mu' of the average-value level within between each existing mean time "level 1" and "level 0" -- ratio Q=mu'/(sigma1+sigma0) of the sum (sigma1+sigma0) of the standard deviation value within each mean time concerned -- (8) may be calculated as a signal-to-noise-ratio multiplier (claim 5).
[0026] in addition -- in this case -- for example, the inside of the sampling point beforehand measured in specific time amount -- maximum and the minimum value -- respectively -- mumax and mumin ** -- when it carries out, it is shown in drawing 7 -- as -- the range of "level 1" -- "-- muth1 -- the above -- mumax -- following" -- carrying out -- the range of "level 0" -- "micrometerin -- the above -- muth0 -- following" -- then, good (claim 6).
[0027] As explained above, this invention differs from the error rate measuring method which performs incorporation and distinction of data on a frequency equal to the bit rate of a lightwave signal, when [of eye pattern opening currently performed conventionally] the best. That is, a lightwave signal is sampled, it asks for the histogram of optical reinforcement, the monitor of the signal-to-noise-ratio multiplier (Q value) time-average-ized from this histogram is carried out, and the lightwave signal quality monitor of this invention is the basic clock frequency f0. It can respond to the lightwave signal of the bit rate Nf0 (bit/s) of the integral multiple of the arbitration of (Hz). Moreover, with the conventional technique, they are dozens difficult Gbit/s by using a sampling in the narrow sampling light pulse of pulse width, and the optical field by the nonlinear optical effect of a high-speed response. The quality of the above ultra high-speed lightwave signal can also be inspected.
[0028]
[Embodiment of the Invention] (The 1st operation gestalt: Claims 1, 7, 8, 9, and 13) Drawing 8 shows the 1st operation gestalt of the lightwave signal quality monitor of this invention.
[0029] drawing -- setting -- a transmission line to basic clock frequency f0 The lightwave signal which has bit rate N-f0 (bit/s) (N= 1, 2, --) of the integral multiple of (Hz) is inputted, and a part of the lightwave signal branches by the optical turnout 51-1. At this time, in order to oppress transmission characteristic degradation by branching loss, the smaller possible one of the branching ratio of the monitor port to a transmission-line port is good. The lightwave signal outputted from the monitor port of the optical turnout 51-1 dichotomizes by the optical turnout 51-2 further.
[0030] While branching by the optical turnout 51-2, it is inputted into the timing clock generating means 11, and a lightwave signal is the basic clock frequency f0. Timing clock (or it added) f0-/n1-deltaf which extracted (Hz) and lengthened offset frequency deltaf (Hz) from 1 for the integer (Hz) (or f0/n1+deltaf (Hz)) It generates. This timing clock is used for the short light pulse generating means 12, and a repeat frequency is f0-/n1-deltaf. A sampling light pulse train with pulse width narrower enough than the time slot of a lightwave signal is generated in (Hz) (or f0/n1+deltaf (Hz)).
[0031] It is multiplexed with the optical multiplexing vessel 2, and the sampling light pulse train outputted from the lightwave signal of another side and the short light pulse generating means 12 which branched by the optical turnout 51-2 is inputted into a non-linear optical material 3. A non-linear optical material 3 generates a lightwave signal and the cross-correlation lightwave signal (SFG, DFG, FWM) of a sampling light pulse. This cross-correlation lightwave signal is changed into a cross-correlation electrical signal with an

optical/electrical converter 4, and is inputted into the electrical signal processing means 5. The electrical signal processing means 5 performs detection and analysis of the peak value of this cross-correlation electrical signal, and measures a histogram as shown in drawing 3 . With the electrical signal processing means 5, it asks for the signal-to-noise-ratio multiplier Q based on the principle mentioned above, and the quality of a lightwave signal is inspected. In the optical-fiber-transmission network where the digital lightwave signal of a different bit rate is transmitted by this, it cannot be based on the bit rate of a lightwave signal, but quality inspection of a lightwave signal can be conducted by single system of measurement.

[0032] Here, response relation with the basic configuration shown in drawing 1 is shown. The timing clock generating means 11 and the short light pulse generating means 12 are equivalent to the sampling light pulse generating means 1. The thing of the other same signs corresponds as it is. In addition, at this operation gestalt, it is the basic clock frequency f0 of a lightwave signal with the timing clock generating means 11. In order to extract, the optical turnout 51-1 and the configuration which uses 51-2 and branches in a part of lightwave signal of a transmission line are taken.

[0033] Drawing 9 shows the example of a configuration of a timing clock generating means. Drawing 9 (a) Setting, the basic bit rate timing generation means 13 is a bit rate N and f0. A lightwave signal to basic clock frequency f0 The clock frequencies f0/n1 of 1 for an integer are generated. An oscillator 14 generates offset frequency deltaf. A mixer 15 mixes clock frequencies f0/n1 and offset frequency deltaf, and generates the timing clock of frequency f0/n1 **deltaf (Hz), and a band pass filter 18 outputs only the frequency component of f0-/n1-deltaf (Hz) or f0/n1+deltaf (Hz) from a mixer output.

[0034] Here, the setting-out approach of offset frequency deltaf is explained. Drawing 10 is a timing diagram which shows the relation on the time-axis of a lightwave signal, sampling light, and the generated sum cycle light. The repeat frequency of sampling light is 1 of the repeat frequency f0 of a lightwave signal/n1. Since only deltaf is small compared with dividing, as shown in drawing 10 , the sweep of the sampling light pulse will be carried out deltaT Shifting a relative position with a lightwave signal each time. Gap deltaT of this relative position is the repeat period Ts (= 1/fs) of sampling light, 1 of a lightwave signal/n1. It is the difference of periodic n1T0 (T0=1/f0) of dividing, and is [0035].

[Equation 1]

$$\Delta T = Ts - n_1 T_0 = \frac{1}{\frac{f_0}{n_1} - \Delta f} - \frac{n_1}{f_0} \fallingdotseq \frac{n_1^2 \Delta f}{f_0^2} \quad \cdots(9)$$

[0036] It is expressed. It is the period T0 of a lightwave signal about gap deltaT of this relative position. n2 It considers as the sum of step time deltaT of twice and a sampling. Namely, deltaT=n2T0+deltaT -- It is referred to as (10). This means sampling a lightwave signal wave by step time deltaT of a sampling. At this time, it is (9). From a formula and (10) types, deltaf is [0037].

[Equation 2]

$$\Delta f = \frac{f_0(n_1 + f_0 \delta T)}{n_1(n_1 + n_2 + f_0 \delta T)} \quad \cdots(11)$$

[0038] It becomes. In addition, n1 and n2 It is the natural number. Therefore, a lightwave signal wave can be sampled by desired amount of sampling steps deltaT by setting up offset frequency deltaf by (11) types. Moreover, n1 And n2 By choosing combination suitably, an offset frequency and a timing clock can be set up according to the band of the sampling light source or a signal-processing system.

[0039] The time resolution in the sampling of this invention is dependent on pulse width deltatau of the sampling light pulse mainly generated with the short light pulse generating means 12, and the speed of response of a non-linear optical material 3. As a short light pulse generating means 12, mode locking fiber laser, mode locking semiconductor laser, gain switching semiconductor laser, etc. can be used. The short light pulse of 1 or less ps of pulse width can be generated by using these light sources now. KTP (molecular formula KTiOPO4) which is the secondary non-linear optical material about SFG and DFG as a non-linear optical material 3 LiNbO3 etc. -- organic materials, such as an inorganic material and AANP, semiconductor waveguide, etc. can be used. About FWM, quartz system optical waveguides, such as an optical fiber which is the 3rd non-linear optical material, can be used. The speed of responses of these ingredients are all. They are 0.1 or less pses. Therefore, 1 or less ps of time resolution is possible by using

the above thing. In addition, this is number of bit rates 100 Gbit/s. It corresponds.
[0040] As an optical multiplexing machine 2, although the usual optical coupler may be used, a sampling light pulse and a lightwave signal can be multiplexed by low loss by using a wavelength multiplexing coupler. Moreover, when the polarization direction of a sampling light pulse and a lightwave signal lies at right angles, it may be made to carry out polarization multiplex by the polarization beam splitter.
[0041] In addition, in using SFG or DFG as a nonlinear optical effect, the non-linear optical materials which can be used according to the polarization direction of a lightwave signal and a sampling light pulse differ. When the polarization directions of both light are parallel, and polarization of two basic light is parallel, it is necessary to use the secondary non-linear optical material which performs "type I phase matching" which cross-correlation light generates efficiently. On the other hand, when the polarization direction of both light is a rectangular cross, and polarization of two basic light is a rectangular cross, it is necessary to use the secondary non-linear optical material which performs "type II phase matching" which cross-correlation light generates efficiently (the above-mentioned reference 2). In using FWM as a nonlinear optical effect, in order to generate cross-correlation light efficiently, it is necessary to set the polarization direction of a lightwave signal and a sampling light pulse as parallel.
[0042] Moreover, what is necessary is just to amplify the peak power of a lightwave signal and a sampling light pulse with the light amplifier arranged before and after the optical multiplexing machine 2, if the conversion efficiency of the non-linear optical material 3 to be used is inadequate. As a light amplifier, the light amplifier and semiconductor laser amplifier using the rare earth addition fiber which added rare earth can be used.
[0043] Moreover, a lightwave signal and a sampling light pulse are contained in the output light of a non-linear optical material 3 besides the sum cycle light (or difference cycle light or 4 light-wave mixing light) which is a cross-correlation lightwave signal. Moreover, depending on conditions, the second higher harmonic of a lightwave signal or a sampling light pulse may also be generated. What is necessary is to insert the wavelength filter 32 between a non-linear optical material 3 and an optical/electrical converter 4, and to choose only a cross-correlation lightwave signal, in degrading the signal-to-noise ratio of the cross-correlation lightwave signal which such light measures.
[0044] (The 2nd operation gestalt: Claims 1, 7, 10, 11, and 13) Drawing 11 shows the 2nd operation gestalt of the lightwave signal quality monitor of this invention. It replaces with the timing clock generating means 11 of the 1st operation gestalt, and the description of this operation gestalt is the basic clock frequency f0. It is in the configuration using a timing clock generating means 16 to generate the timing clock of f0-/n1-deltaf (or f0/n1+deltaf), from the synchronous-network clock signal which has clock frequency f0 / m of 1 for an integer (m= 1, 2, --). In addition, what is necessary is just to set up offset frequency deltaf based on the above-mentioned (11) types. Other configurations are the same as that of the 1st operation gestalt.
[0045] The configuration of the timing clock generating means 16 is drawing 9 (b). It is the network synchronization clock signal of bit rate f0 / m to the basic clock frequency f0 so that it may be shown. What is necessary is just to use a basic bit rate timing generation means 17 to generate the clock frequencies f0/n1 of 1 for an integer.
[0046] Moreover, as it replaces with the timing clock generating means 11 (drawing 9 (a)) of the 1st operation gestalt, and the timing clock generating means 16 (drawing 9 (b)) of the 2nd operation gestalt and is shown in drawing 9 (c) The oscillator which oscillates timing clock f0-/n1-deltaf or f0-/n1+deltaf which adjusted offset frequency deltaf of (11) types from the clock frequencies f0/n1 of 1 for an integer of a basic clock frequency may be used as a timing clock generating means (claim 12).
[0047] (The 3rd operation gestalt: Claims 1, 7, 8, 13, and 14) Drawing 12 shows the 3rd operation gestalt of the lightwave signal quality monitor of this invention. Generally the nonlinear optical effect used by this invention has the polarization dependency, and the cross-correlation lightwave signal power generated according to the polarization condition of the lightwave signal to input changes. This operation gestalt has the composition of removing this polarization dependency.
[0048] Namely, an input and an output use two ports of a certain polarization beam splitters 21 at a time as an optical multiplexing machine 2 in the 1st operation gestalt. Input a lightwave signal and a sampling light pulse train into each input port, and a non-linear optical material 3-1, 3-2, the wavelength filter 32-1, 32-2, an optical/electrical converter 4-1, and 4-2 are connected to each output port. It is the configuration of adding the cross-correlation electrical signal outputted from each optical/electrical converter in an adder circuit 22, and inputting it into the electrical signal processing means 5.

[0049] Here, polarization of the sampling light pulse train inputted into the polarization beam splitter 21 is set as the linearly polarized light which inclined 45 degrees to the polarization main shaft of the polarization beam splitter 21. At this time, the lightwave signal inputted into the polarization beam splitter 21 and a sampling light pulse train are divided into two polarization components (Psig.p, Psig.s), and (Psam.p and Psam.s) which intersect perpendicularly, respectively. And polarization composition is carried out and components (Psig.p, Psam.s), and (Psig.s and Psam.p) which intersect perpendicularly mutually [2 light] are outputted to each output port. The lightwave signal and sampling light pulse train which were outputted to each output port are changed into a cross-correlation lightwave signal by the non-linear optical material 3-1 prepared according to the individual, respectively, and 3-2, and are further changed into a cross-correlation electrical signal by the optical/electrical converter 4-1 and 4-2. These two cross-correlation electrical signals are added in an adder circuit 22, are inputted into the electrical signal processing means 5, are processed like the 1st operation gestalt, ask for the signal-to-noise-ratio multiplier Q, and inspect the quality of a lightwave signal.
[0050] With this operation gestalt, two polarization component Psam.p after the polarization beam splitter 21 and Psam.s are made equal by making polarization of a sampling light pulse train into the linearly polarized light which inclined 45 degrees to the polarization main shaft of the polarization beam splitter 21. That is, it is Psam about all the power of a sampling light pulse train. When it carries out, it is Psam.p=Psam.s= 0.5Psam. -- It is set to (12). On the other hand, the polarization condition at the time of carrying out incidence of the lightwave signal to the polarization beam splitter 21 is not being fixed. Therefore, a lightwave signal is divided into two polarization component Psig.p of the power ratio of arbitration, and Psig.s by the polarization beam splitter 21. However, it is fixed and the sum of these two components is Psig about all the power of a lightwave signal. It is Psig.p+Psig.s=Psig when it carries out. -- It is set to (13).
[0051] The sum total Pint of the power of a cross-correlation lightwave signal which will be generated here in a non-linear optical material 3-1 and 3-2 if conversion efficiency of a nonlinear optical effect is set to eta Pint =etaPsig.p Psam. s+eta Psig.s Psam.p -- It is set to (14). (14) When (12) types and (13) types are substituted for a formula, it is Pint = 0.5etaPsig Psam. -- It is set to (15). This (15) type means that the sum of two cross-correlation lightwave signals is not dependent on the polarization condition of the lightwave signal inputted.
[0052] However, (15) types may not be materialized according to the individual difference of a gap of the branching ratio of the polarization beam splitter 21, and the conversion efficiency of two non-linear optical materials, but a polarization dependency may arise slightly. In this case, what is necessary is just to perform weighting suitably for the level of two cross-correlation electrical signals in an adder circuit 22 so that the level of the added cross-correlation electrical signal may not be dependent on the polarization condition of a lightwave signal.
[0053] By carrying out the monitor of the S/N sequence with such a configuration, quality inspection of the lightwave signal stabilized without not being based on the bit rate of a lightwave signal, and being based on the polarization condition of a lightwave signal can be conducted.
[0054] In addition, also in this operation gestalt, it may replace with the timing clock generating means 11, and a timing clock generating means 16 to generate the timing clock of f0 / n1-deltaf (or f0/n1+deltaf) from the network synchronization clock signal of bit rate f0 / m may be used like the 2nd operation gestalt (claim 10). Moreover, the timing clock generating means which consists of only oscillators as mentioned above may be used (claim 12).
[0055] (The 4th operation gestalt: Claims 1, 7, 8, 13, and 15) Drawing 13 shows the 4th operation gestalt of the lightwave signal quality monitor of this invention. The description of this operation gestalt is replaced with the adder circuit 22 of the 3rd operation gestalt, doubles the timing of two cross-correlation lightwave signals with the optical delay means 23, and is in the configuration which carries out polarization composition by the polarization beam splitter 24 and which is inputted into an optical/electrical converter 4. Other configurations are the same as that of the 3rd operation gestalt.
[0056] (The 5th operation gestalt: Claims 1, 7, 10, and 16) Drawing 14 shows the 5th operation gestalt of the lightwave signal quality monitor of this invention. the 1- with the 4th operation gestalt, in order to inspect the quality of the lightwave signal of a transmission line, it is necessary to branch a part of lightwave signal by the optical turnout 51-1, and loss of the lightwave signal of a transmission line is not avoided. Moreover, if the branching ratio to a monitor system is made low in order to suppress this

lightwave signal loss to the minimum, even if it amplifies with a light amplifier, a signal-to-noise ratio will deteriorate and sufficient cross-correlation lightwave signal will not be acquired.
[0057] The description of this operation gestalt is in the configuration which reduces the loss done to the lightwave signal of a transmission line by inputting a sampling light pulse train into a transmission line, generating a cross-correlation lightwave signal, and carrying out wavelength separation of a lightwave signal and the cross-correlation lightwave signal.
[0058] That is, the sampling light pulse train of frequency f0-/n1-deltaf (or f0/n1+deltaf) is repeatedly generated from the network synchronization clock signal of bit rate f0 / m with the timing clock generating means 16 and the short light pulse generating means 12. On the other hand, the optical multiplexing machine 2, a non-linear optical material 3, and the wavelength filter 33 are inserted all over a transmission line, it multiplexs with the optical multiplexing vessel 2, the lightwave signal and sampling light pulse train which have been sent from the transmission line of the upstream are inputted into a non-linear optical material 3, and a cross-correlation lightwave signal is generated.
[0059] The output light of a non-linear optical material 3 is the sum cycle light (optical frequency omegasfg =omega sam+omega sig), difference cycle light (optical frequency omegasfg =omega sam-omega sig), or 4 light-wave mixing light (optical frequency omegafwm =2omega sam-omega sig) which is a lightwave signal (optical frequency omegasig), a sampling light pulse (optical frequency omegasam), and a cross-correlation lightwave signal. Moreover, depending on conditions, the second higher harmonic (optical frequency sig of 2omega) of a lightwave signal and the second optical frequency (sam) higher harmonic of 2omega of a sampling light pulse may occur. The wavelength filter 33 separates a lightwave signal and a cross-correlation lightwave signal into a different port according to an individual from such light. And the separated lightwave signal is sent out to a down-stream transmission line, a cross-correlation lightwave signal is inputted into an optical/electrical converter 4, and it changes into a cross-correlation electrical signal, and it processes like the 1st operation gestalt with the electrical signal processing means 5, and asks for the signal-to-noise-ratio multiplier Q, and the quality of a lightwave signal is inspected.
[0060] Quality inspection of a lightwave signal can be conducted without not being based on the bit rate of a lightwave signal, and degrading the S/N of the lightwave signal of a transmission line by carrying out the monitor of the S/N sequence with such a configuration.
[0061] (The 6th operation gestalt: Claims 1, 7, 10, 16, and 17) Drawing 15 shows the 6th operation gestalt of the lightwave signal quality monitor of this invention. The description of this operation gestalt is in the configuration which combined the 3rd operation gestalt and the 5th operation gestalt. That is, it has the composition of it not being dependent on the polarization condition of a lightwave signal, and reducing loss of the lightwave signal of a transmission line.
[0062] Incidence of the lightwave signal sent from the transmission line of the upstream and the sampling light pulse train is carried out from input port which is different in the polarization beam splitter 21. At this time, polarization of a sampling light pulse train is set as the linearly polarized light which inclined 45 degrees to the polarization main shaft of the polarization beam splitter 21. In the polarization beam splitter 21, it separates into two polarization components (Psig.p, Psig.s), and (Psam.p, Psam.s) which intersect perpendicularly, and a lightwave signal and a sampling light pulse train are outputted to the components (Psig.p, Psam.s) which intersect perpendicularly mutually [2 light], and the output port where polarization composition is carried out and Psig.s differs from (Psam.p), respectively.
[0063] The lightwave signal and sampling light pulse train which were outputted to each output port are changed into a cross-correlation lightwave signal by the non-linear optical material 3-1 prepared according to the individual, respectively, and 3-2, and are further divided into a lightwave signal and a cross-correlation lightwave signal by the wavelength filter 33-1 and 33-2, respectively. Two separated lightwave signals double timing with the optical delay means 25, carry out polarization composition by the polarization beam splitter 26, and are sent out to the transmission line of the downstream. On the other hand, two separated cross-correlation lightwave signals are changed into a cross-correlation electrical signal by the optical/electrical converter 4-1 and 4-2, respectively, are added further in an adder circuit 22, are inputted into the electrical signal processing means 5, are processed like the 1st operation gestalt, ask for the signal-to-noise-ratio multiplier Q, and inspect the quality of a lightwave signal.
[0064] Quality inspection of the lightwave signal stabilized without being further based on the polarization condition of a lightwave signal can be conducted without not being based on the bit rate of a lightwave signal, and degrading the S/N of the lightwave signal of a transmission line by carrying out the monitor of

the S/N sequence with such a configuration.
[0065] (The 7th operation gestalt: Claims 1, 7, 10, 16, and 18) Drawing 16 shows the 7th operation gestalt of the lightwave signal quality monitor of this invention. The description of this operation gestalt is in the configuration which combined the 4th operation gestalt and the 5th operation gestalt. That is, it has the composition of it not being dependent on the polarization condition of a lightwave signal, and reducing loss of the lightwave signal of a transmission line.
[0066] It is the configuration of replacing with the adder circuit 22 of the 6th operation gestalt, doubling the timing of two cross-correlation lightwave signals with the optical delay means 23 in this operation gestalt, carrying out polarization composition by the polarization beam splitter 24, and inputting into an optical/electrical converter 4. Other configurations are the same as that of the 6th operation gestalt.
[0067] (The 8th operation gestalt: Claim 2) Drawing 17 shows the 8th operation gestalt of the lightwave signal quality monitor of this invention. drawing -- setting -- a transmission line to basic clock frequency f0 The lightwave signal which has bit rate N and f0 (bit/s) of the integral multiple of (Hz) (N= 1, 2, --) is inputted, and a part of the lightwave signal branches by the optical turnout 51. At this time, in order to oppress transmission characteristic degradation by branching loss, the smaller possible one of the branching ratio of the monitor port to a transmission-line port is good. The lightwave signal which branched by the optical turnout 51 is changed into an electrical signal with an optical/electrical converter 61, and is inputted into the electrical signal processing means 62. In addition, what is necessary is just to amplify using a light amplifier, if the reinforcement of the lightwave signal inputted into an optical/electrical converter 61 is insufficient.
[0068] The timing clock generating means 63 is the basic clock frequency f0. Frequency f0-/n1-deltaf which adjusted offset frequency deltaf (Hz) from 1 for an integer of (Hz) (Hz) or f0/n1+deltaf The timing clock of (Hz) is generated. In addition, the timing clock generating means 63 is drawing 9 (a) and (b). The shown configuration or drawing 9 (c) Any of the configuration of only the shown oscillator are sufficient (claims 9, 11, and 12). In addition, drawing 9 (a) In taking a configuration, an optical turnout is arranged between the optical turnout 51 and an optical/electrical converter 61, and it inputs the branched lightwave signal into the timing clock generating means 63. Moreover, drawing 9 (b) In taking a configuration, it inputs a synchronous-network clock signal into the timing clock generating means 63.
[0069] The electrical signal processing means 62 samples an electrical signal using this timing clock, and measures the histogram of optical reinforcement. and the sampling point which constitutes the histogram to "level 1" and "level 0" -- the difference of the average-value level within between each existing mean time, and "level 1" and "level 0" -- the time amount from the ratio of the sum of the standard deviation value within each mean time concerned -- average Q value is calculated and the quality of a lightwave signal is inspected.
[0070] The description of this operation gestalt is in the place which performs a sampling in an electric stage instead of the sampling by **** shown in drawing 1 and each above-mentioned operation gestalt. Performance monitoring of the lightwave signal of the bit rate of arbitration can be performed like [the configuration of this operation gestalt] each above-mentioned operation gestalt (claims 3-6). However, the bit rates of the lightwave signal which can respond are dozens Gbit/s by the band and processing speed of an optical/electrical converter or an electrical signal processing means. It is restricted to extent. However, to the optical-fiber-transmission network where it turns out that the highest bit rate does not exceed this limit, it is applicable.
[0071]
[Effect of the Invention] With the conventional technique, they are dozens difficult Gbit/s by the lightwave signal quality monitor of this invention sampling a lightwave signal, as explained above, and asking for the histogram of optical reinforcement, carrying out the monitor of the signal-to-noise-ratio multiplier (Q value) time-average-ized from this histogram, and using a sampling in an optical field. The quality of the above ultra high-speed lightwave signal can be inspected. Namely, 1 Mbit/s From class 100 Gbit/s The monitor of the quality of the signal of two or more bit rates far-reaching [with a signal] can be carried out in a single monitor circuit.
[0072] Moreover, dozens Gbit/s It is possible to carry out the monitor of the signal-to-noise-ratio multiplier (Q value) to the quality inspection of the lightwave signal to extent also by the configuration which performs a sampling in an electric stage.
[0073] In addition, in the optical-fiber-transmission network using the light amplifier as a repeater, although

a signal bit rate can be chosen flexibly, the lightwave signal quality monitor of this invention can carry out the monitor of the quality of the lightwave signal in such an optical-fiber-transmission network. Moreover, it is applicable not only to SDH but the transmission line which transmits a PDH signal by expanding or changing a bit rate in the range in which a sampling light pulse generating means can respond.

[Translation done.]

TECHNICAL FIELD

[Field of the Invention] This invention relates to the lightwave signal quality monitor which carries out the monitor of the signal-to-noise ratio of a lightwave signal in the optical-fiber-transmission network where the digital lightwave signal of a different bit rate is transmitted.

[Translation done.]

* NOTICES *

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1.This document has been translated by computer. So the translation may not reflect the original precisely.

2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

PRIOR ART

[Description of the Prior Art] In SDH (Synchronous Digital Hierarchy) which became global unification network ladder structure in the 1990s, identification and the change seizing signal of the failure section have been acquired by carrying out parity check called bit interleave parity between the multiplexing terminal offices (BIP-Nx24) between repeaters (BIP-8), respectively. Here, N is N of STM-N showing the number of multiplexing, and is 156 Mbit/s. The ladder of the integral multiple is expressed as STM-N on the basis of STM-1. In addition, N= 1, and 4, 16 and 64 are recognized internationally. BIP-M means the parity check in every M bits, and a M-bit check bit is obtained. Parity check with parallel M bits of the signal in a frame is performed by the transmitting side, the check bit is stored in the following frame, and it transmits with the main signal. In a receiving side, same parity check is conducted and a transmission error is detected by collating with the check bit stored in the predetermined location of degree frame.
[0003] Drawing 18 shows the example of a configuration of the conventional error rate system of measurement. In drawing, a part of lightwave signal from a transmission line branches by the optical turnout 51-1, it is amplified with a light amplifier 52, and dichotomizes by the optical turnout 51-2 further. While branching by the optical turnout 51-2, it is inputted into the clock extract circuit 53, and a lightwave signal is the bit rate Nf0 of a lightwave signal. Clock f0 which responded It is extracted. The lightwave signal of another side which branched by the optical turnout 51-2 is inputted into a receiving circuit 54, and is inputted into the error rate detector 55 where the output consists of a frame detector, a parity check circuit, and a correlation circuit further. A receiving circuit 54 and the error rate detector 55 are the clock f0 extracted in the clock extract circuit 53. It responds and operates and the error rate of a lightwave signal is measured. In addition, the thing of the configuration according to the bit rate of a lightwave signal is required for the clock extract circuit 53, a receiving circuit 54, and the error rate detector 55. That is, in order to perform error rate detection corresponding to two or more bit rates, it is necessary to prepare the circuit corresponding to each bit rate, and cannot respond in a single circuit.
[0004] By the way, in order to evaluate a transmission system, the method of measuring the error rate of a signal directly is common. However, by this approach, there was a problem to which the measuring time becomes this thing for a long time in the case of a very low error rate, and working efficiency becomes low.

[0005] Then, the method of presuming the error rate in the optimal operating point from the inclination of the error rate acquired when changing the threshold of a discrimination circuit was devised (reference 1:N.S.Bergano et al., "Margin Measurement in Optical Amplifier Systems", IEEE Photonics Technology Letters, vol.5, no.3, pp.304-306). . The eye pattern and the histogram on the strength [optical] of a lightwave signal are shown in drawing 19 . When eye opening of this eye pattern becomes max (discernment point), by changing the threshold of a discrimination circuit, "yes" or "1" level in binary transmission, and a "low" or "0" level are distinguished, and the rate of the error at that time is measured.
[0006] The system of measurement by the clock extract circuit 53 as shown in drawing 20 , the optical/electrical converter 56, and the electrical signal processing means 57 is constituted actually, and it is considering as the assessment index in quest of the Q value which is equivalent to a signal-to-noise ratio from the threshold dependency of an error rate. That is, a part of lightwave signal from a transmission line is changed into an electrical signal with an optical/electrical converter 56, the clock extracted in this electrical signal and the clock extract circuit 53 is inputted into an electrical signal processing means 57 like a sampling oscilloscope, and an eye pattern like drawing 19 and a histogram on the strength [optical]

are obtained.
[0007] Time amount t0 from which eye opening of this eye pattern serves as max Set and signal amplitude (for example, electrical-potential-difference value) is set to mu (t0). When the standard deviation of the noise of "yes" or "1" level in binary transmission is set to sigma0 (t0), Q (t0) value the standard deviation of the noise of sigma1 (t0), "low", or "0" level Q(t0) =mu(t0)/(sigma1(t0)+sigma0 (t0)) -- It defines as (1). On the other hand, when the noise amplitude distribution of a gauss mold is assumed, in the low field of an error rate, error rate P and Q value are P=(1/(Q(2pi) 1/2)) exp (-Q2/2). -- There is relation as shown in (2). Therefore, if Q value can be measured, a transmission-line error rate can be presumed.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] With the conventional technique, they are dozens difficult Gbit/s by the lightwave signal quality monitor of this invention sampling a lightwave signal, as explained above, and asking for the histogram of optical reinforcement, carrying out the monitor of the signal-to-noise-ratio multiplier (Q value) time-average-ized from this histogram, and using a sampling in an optical field. The quality of the above ultra high-speed lightwave signal can be inspected. Namely, 1 Mbit/s From class 100 Gbit/s The monitor of the quality of the signal of two or more bit rates far-reaching [with a signal] can be carried out in a single monitor circuit.
[0072] Moreover, dozens Gbit/s It is possible to carry out the monitor of the signal-to-noise-ratio multiplier (Q value) to the quality inspection of the lightwave signal to extent also by the configuration which performs a sampling in an electric stage.
[0073] In addition, in the optical-fiber-transmission network using the light amplifier as a repeater, although a signal bit rate can be chosen flexibly, the lightwave signal quality monitor of this invention can carry out the monitor of the quality of the lightwave signal in such an optical-fiber-transmission network. Moreover, it is applicable not only to SDH but the transmission line which transmits a PDH signal by expanding or changing a bit rate in the range in which a sampling light pulse generating means can respond.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] However, since the wave was sampled after the conventional Q value system of measurement changed the lightwave signal into the electrical signal, as shown in drawing 20 , and Q value was calculated, the bit rate of the lightwave signal which can respond with the band and processing speed of an optical/electrical converter or an electrical signal processing circuit was restricted to 40 Gbit/s extent.
[0009] Moreover, since the Q value in the event of eye opening serving as max was measured, it was not able to respond to the digital lightwave signal of a different bit rate. Moreover, since the conventional Q value system of measurement needs to branch the lightwave signal for monitors from a transmission line, loss by branching arises in the lightwave signal on a transmission line, and it has become the factor which degrades a signal-to-noise ratio.
[0010] This invention aims at offering the lightwave signal quality monitor which cannot be based on the bit rate of a measuring beam-ed signal, but can carry out the monitor of the signal-to-noise ratio in a single circuit in the optical-fiber-transmission network where the digital lightwave signal of a different bit rate is transmitted.
[0011] Moreover, this invention is dozens Gbit/s. It aims at offering the lightwave signal quality monitor which can respond also to the lightwave signal of the above bit rate. Moreover, this invention aims at offering the lightwave signal quality monitor which can reduce the effect which it has on the signal-to-noise ratio of the lightwave signal of a transmission line.

[Translation done.]

MEANS

[Means for Solving the Problem] A lightwave signal quality monitor according to claim 1 is a configuration which carries out the monitor of the signal-to-noise ratio with an optical means from the statistics processing value of the amplitude value of the histogram on the strength [optical] by the bit rate of a lightwave signal to a sampling point. Hereafter, the basic configuration is explained.
[0013] Drawing 1 shows the basic configuration of a lightwave signal quality monitor according to claim 1. the lightwave signal inputted from a transmission line in drawing -- optical frequency omegasig -- basic clock frequency f0 It has bit rate N-f0 (bit/s) (N= 1, 2, --) of the integral multiple of (Hz). The sampling light pulse generating means 1 Optical frequency omegasam, basic clock frequency f0 1 for an integer of (Hz) and offset frequency deltaf (Hz) were adjusted -- repeating -- frequency f0-/n1-deltaf (Hz) (n (or f0/n1+deltaf (Hz)) 1 = 1, 2, --) Pulse width deltatau generates a sampling light pulse narrower (deltatau<<1/Nf0) enough than the time slot of a lightwave signal. The optical multiplexing machine 2 multiplexs and inputs a lightwave signal and a sampling light pulse into a non-linear optical material 3.
[0014] A non-linear optical material 3 is sum cycle light generating (SFG:Sum Frequency Generation) (reference 2: Takayoshi others) which is one of the secondary nonlinear optical effects. "The ultra high-speed light wave form measuring method by the optical sampling using sum cycle light generating", The Institute of Electronics, Information and Communication Engineers paper magazine, B-I, vol.J75-B-I, no.5, pp.372-380, 1992 and difference cycle light generating (DFG:Defference Frequency Generation), 4 light-wave mixing (FWM:Four Wave Mixing) (reference 3-.A.Andrekson, Electron.Lett.27, p.1440, 1991) which is the 3rd nonlinear optical effect is used. A lightwave signal and the cross-correlation lightwave signal of a sampling light pulse are generated.
[0015] Drawing 2 (a), (b), and (c) The relation of the optical frequency in SFG, DFG, and FWM is shown, respectively. SFG is drawing 2 (a). It is optical frequency omegasig so that it may be shown. A lightwave signal and optical frequency omegasam When incidence of the two light waves of a sampling light pulse is carried out to the secondary non-linear optical material, it is the phenomenon which the light of peace optical frequency omegasfg (=omega sam+omega sig) generates. DFG is drawing 2 (b). It is optical frequency omegasig so that it may be shown. A lightwave signal and optical frequency omegasam It is the phenomenon which the light of optical frequency omegadfg (=omega sam-omega sig) of a difference generates from a sampling light pulse.
[0016] Although FWM is a phenomenon which a new light (optical frequency omega4=omega1+omega2-omega3) generally generates from three incident light (optical frequency omega1, omega2, and omega3), in applying to an optical sampling, since a configuration becomes complicated, using three kinds of light uses FWM to which two light waves usually degenerated (omega1=omega2). omega 1 and omega 2 ****** -- the sampling light pulse of optical frequency omegasam -- incidence -- carrying out -- omega 3 ****** -- optical frequency omegasig carrying out incidence of the lightwave signal -- drawing 2 (c) The light of optical frequency omegafwm (=2omega sam-omega sig) is generated so that it may be shown. [namely,]
[0017] Here, the repeat frequency of a sampling light pulse is the basic clock frequency f0 of a lightwave signal. 1/n1 By comparing, since only deltaf is small, the sweep of the sampling light pulse will be carried out, shifting a relative position with a lightwave signal. Consequently, it changes, as a cross-correlation lightwave signal is shown in drawing 1 , and the envelope serves as a wave to which the time-axis of a lightwave signal wave was expanded. By detecting this cross-correlation lightwave signal by the light-receiving system, measurement of the histogram of the optical reinforcement of a high-speed lightwave

signal is attained (the above-mentioned reference 2).
[0018] That is, a cross-correlation lightwave signal is changed into an electrical signal with an optical/electrical converter 4, and is inputted into the electrical signal processing means 5. With the electrical signal processing means 5, detection and analysis of the peak value of a cross-correlation electrical signal are performed, and the histogram of optical reinforcement as shown in drawing 3 is measured. And the inside of the sampling point which constitutes the histogram of this optical reinforcement, Threshold level muth1 defined beforehand A high point group is made into "level 1." moreover, threshold level muth0 defined separately a low point group -- "level 0" -- carrying out -- "level 1" and "level 0" -- the average mu 1 within each existing mean time, and mu 0 With Difference mu "level 1" and "level 0" -- ratio Q=mu/(sigma1+sigma0) of the sum (sigma1+sigma0) of the standard deviation value within each mean time concerned -- (3) is calculated as a signal-to-noise-ratio multiplier (claim 3).
[0019] Here, they are above threshold level muth1 and muth0. An example of the approach of determining is explained with reference to drawing 4 (claim 4). First, the electrical signal processing means 5 is mean value mum about the level when asking for the histogram of level from the sampling point beforehand measured in specific time amount, integrating with the number of sampling points from the level maximum of this histogram, and becoming equal to the number Nmiddle of sampling points. It carries out. In addition, the number Nmiddle of sampling points is Nmiddle=NtotalxDxM, when the duty ratio (ratio of pulse width and a time slot) of Ntotal and a lightwave signal is set to D and it sets a mark rate (probability of occurrence of the mark "1" in digital transmission) to M for the total number of sampling points. -- It asks as (4). Moreover, the average mu 1 of "level 1" mu1 =2(micrometer-mu 0)+mu0 -- It is assumed that it is (5).
[0020] next, the level to which the number of sampling points serves as peak value from a level minimum value side in the above-mentioned histogram at the beginning -- the average mu 0 of "level 0" ** -- it carries out. Moreover, "level 0" and threshold level muth0 of "level 1", and muth1 muth0 =mu0+alpha(mu1-mu0) muth1 =mu1-alpha (mu1-mu0) -- It sets up with (6). However, 0< alpha<0.5 It carries out. this -- (6) types if (5) types are substituted -- muth0 =2alphamum+(1-2alpha) mu0microth1 =2(1-alpha) mum-(1-2alpha) mu0 -- (7) is obtained.
[0021] threshold level muth0 determined by the above approach, and muth1 the histogram of the optical reinforcement calculated from total measured value -- the average mu 1 of "level 1" and "level 0", and mu 0 And standard deviation sigma1 and sigma0 It asks and an average signal-to-noise-ratio multiplier (Q value) is calculated from these values.
[0022] This signal-to-noise-ratio multiplier Q is the physical quantity corresponding to 1 to 1 to the signal-to-noise ratio of a lightwave signal. Therefore, the quality of the transmitted lightwave signal can be inspected by calculating this Q value.
[0023] Drawing 5 is [the average Q value calculated by the above-mentioned approach, and] time amount t0. Relation with the Q value which can be set is shown. drawing -- alpha -- 0.1 If it carries out, in order that the number of sampling points may decrease, dispersion in average Q value becomes large. On the other hand, it is alpha. Since the measured value near the cross point of an eye pattern is contained when it becomes 0.4 or more, the value of average Q value becomes low and the accuracy of measurement worsens. On the other hand, 0.1< alpha<0.4 Since the number of sampling points is also enough and the effect of a cross point can also be avoided, a case is average Q value and time amount t0. Correlation good between the Q value which can be set is acquired. In addition, in this example, a correlation coefficient is carried out and the high value of **** 0.99 is acquired.
[0024] (7) it sets at a ceremony -- 0.1< alpha<0.4 setting up -- each threshold level muth0 and muth1 By determining, the lightwave signal quality of a transmission line can be supervised with a sufficient precision. [therefore,]
[0025] Moreover, the inside of the sampling point which constitutes a histogram as shown in drawing 6 , the inside of two fields appointed beforehand -- the point group in a high level field -- "level 1" -- carrying out -- the point group in a low level field -- "level 0" -- carrying out -- "level 1" and "level 0" -- with difference mu' of the average-value level within between each existing mean time "level 1" and "level 0" -- ratio Q=mu'/(sigma1+sigma0) of the sum (sigma1+sigma0) of the standard deviation value within each mean time concerned -- (8) may be calculated as a signal-to-noise-ratio multiplier (claim 5).
[0026] in addition -- in this case -- for example, the inside of the sampling point beforehand measured in specific time amount -- maximum and the minimum value -- respectively -- mumax and mumin ** --

when it carries out, it is shown in drawing 7 -- as -- the range of "level 1" -- "-- muth1 -- the above -- mumax -- following" -- carrying out -- the range of "level 0" -- "micrometerin -- the above -- muth0 -- following" -- then, good (claim 6).

[0027] As explained above, this invention differs from the error rate measuring method which performs incorporation and distinction of data on a frequency equal to the bit rate of a lightwave signal, when [of eye pattern opening currently performed conventionally] the best. That is, a lightwave signal is sampled, it asks for the histogram of optical reinforcement, the monitor of the signal-to-noise-ratio multiplier (Q value) time-average-ized from this histogram is carried out, and the lightwave signal quality monitor of this invention is the basic clock frequency f0. It can respond to the lightwave signal of the bit rate Nf0 (bit/s) of the integral multiple of the arbitration of (Hz). Moreover, with the conventional technique, they are dozens difficult Gbit/s by using a sampling in the narrow sampling light pulse of pulse width, and the optical field by the nonlinear optical effect of a high-speed response. The quality of the above ultra high-speed lightwave signal can also be inspected.

[0028]

[Embodiment of the Invention] (The 1st operation gestalt: Claims 1, 7, 8, 9, and 13) Drawing 8 shows the 1st operation gestalt of the lightwave signal quality monitor of this invention.

[0029] drawing -- setting -- a transmission line to basic clock frequency f0 The lightwave signal which has bit rate N-f0 (bit/s) (N= 1, 2, --) of the integral multiple of (Hz) is inputted, and a part of the lightwave signal branches by the optical turnout 51-1. At this time, in order to oppress transmission characteristic degradation by branching loss, the smaller possible one of the branching ratio of the monitor port to a transmission-line port is good. The lightwave signal outputted from the monitor port of the optical turnout 51-1 dichotomizes by the optical turnout 51-2 further.

[0030] While branching by the optical turnout 51-2, it is inputted into the timing clock generating means 11, and a lightwave signal is the basic clock frequency f0. Timing clock (or it added) f0-/n1-deltaf which extracted (Hz) and lengthened offset frequency deltaf (Hz) from 1 for the integer (Hz) (or f0/n1+deltaf (Hz)) It generates. This timing clock is used for the short light pulse generating means 12, and a repeat frequency is f0-/n1-deltaf. A sampling light pulse train with pulse width narrower enough than the time slot of a lightwave signal is generated in (Hz) (or f0/n1+deltaf (Hz)).

[0031] It is multiplexed with the optical multiplexing vessel 2, and the sampling light pulse train outputted from the lightwave signal of another side and the short light pulse generating means 12 which branched by the optical turnout 51-2 is inputted into a non-linear optical material 3. A non-linear optical material 3 generates a lightwave signal and the cross-correlation lightwave signal (SFG, DFG, FWM) of a sampling light pulse. This cross-correlation lightwave signal is changed into a cross-correlation electrical signal with an optical/electrical converter 4, and is inputted into the electrical signal processing means 5. The electrical signal processing means 5 performs detection and analysis of the peak value of this cross-correlation electrical signal, and measures a histogram as shown in drawing 3 . With the electrical signal processing means 5, it asks for the signal-to-noise-ratio multiplier Q based on the principle mentioned above, and the quality of a lightwave signal is inspected. In the optical-fiber-transmission network where the digital lightwave signal of a different bit rate is transmitted by this, it cannot be based on the bit rate of a lightwave signal, but quality inspection of a lightwave signal can be conducted by single system of measurement.

[0032] Here, response relation with the basic configuration shown in drawing 1 is shown. The timing clock generating means 11 and the short light pulse generating means 12 are equivalent to the sampling light pulse generating means 1. The thing of the other same signs corresponds as it is. In addition, at this operation gestalt, it is the basic clock frequency f0 of a lightwave signal with the timing clock generating means 11. In order to extract, the optical turnout 51-1 and the configuration which uses 51-2 and branches in a part of lightwave signal of a transmission line are taken.

[0033] Drawing 9 shows the example of a configuration of a timing clock generating means. Drawing 9 (a) Setting, the basic bit rate timing generation means 13 is a bit rate N and f0. A lightwave signal to basic clock frequency f0 The clock frequencies f0/n1 of 1 for an integer are generated. An oscillator 14 generates offset frequency deltaf. A mixer 15 mixes clock frequencies f0/n1 and offset frequency deltaf, and generates the timing clock of frequency f0/n1 **deltaf (Hz), and a band pass filter 18 outputs only the frequency component of f0-/n1-deltaf (Hz) or f0/n1+deltaf (Hz) from a mixer output.

[0034] Here, the setting-out approach of offset frequency deltaf is explained. Drawing 10 is a timing

diagram which shows the relation on the time-axis of a lightwave signal, sampling light, and the generated sum cycle light. The repeat frequency of sampling light is 1 of the repeat frequency f0 of a lightwave signal/n1. Since only deltaf is small compared with dividing, as shown in drawing 10 , the sweep of the sampling light pulse will be carried out deltaT Shifting a relative position with a lightwave signal each time. Gap deltaT of this relative position is the repeat period Ts (= 1/fs) of sampling light, 1 of a lightwave signal/n1. It is the difference of periodic n1T0 (T0=1/f0) of dividing, and is [0035].
[Equation 1]

$$\Delta T = Ts - n_1 T_0 = \frac{1}{\frac{f_0}{n_1} - \Delta f} - \frac{n_1}{f_0} \fallingdotseq \frac{n_1^2 \Delta f}{f_0^2} \quad \cdots(9)$$

[0036] It is expressed. It is the period T0 of a lightwave signal about gap deltaT of this relative position. n2 It considers as the sum of step time deltaT of twice and a sampling. Namely, deltaT=n2T0+deltaT -- It is referred to as (10). This means sampling a lightwave signal wave by step time deltaT of a sampling. At this time, it is (9). From a formula and (10) types, deltaf is [0037].
[Equation 2]

$$\Delta f = \frac{f_0(n_1 + f_0 \delta T)}{n_1(n_1 + n_2 + f_0 \delta T)} \quad \cdots(11)$$

[0038] It becomes. In addition, n1 and n2 It is the natural number. Therefore, a lightwave signal wave can be sampled by desired amount of sampling steps deltaT by setting up offset frequency deltaf by (11) types. Moreover, n1 And n2 By choosing combination suitably, an offset frequency and a timing clock can be set up according to the band of the sampling light source or a signal-processing system.
[0039] The time resolution in the sampling of this invention is dependent on pulse width deltatau of the sampling light pulse mainly generated with the short light pulse generating means 12, and the speed of response of a non-linear optical material 3. As a short light pulse generating means 12, mode locking fiber laser, mode locking semiconductor laser, gain switching semiconductor laser, etc. can be used. The short light pulse of 1 or less ps of pulse width can be generated by using these light sources now. KTP (molecular formula KTiOPO4) which is the secondary non-linear optical material about SFG and DFG as a non-linear optical material 3 LiNbO3 etc. -- organic materials, such as an inorganic material and AANP, semiconductor waveguide, etc. can be used. About FWM, quartz system optical waveguides, such as an optical fiber which is the 3rd non-linear optical material, can be used. The speed of responses of these ingredients are all. They are 0.1 or less pses. Therefore, 1 or less ps of time resolution is possible by using the above thing. In addition, this is number of bit rates 100 Gbit/s. It corresponds.
[0040] As an optical multiplexing machine 2, although the usual optical coupler may be used, a sampling light pulse and a lightwave signal can be multiplexed by low loss by using a wavelength multiplexing coupler. Moreover, when the polarization direction of a sampling light pulse and a lightwave signal lies at right angles, it may be made to carry out polarization multiplex by the polarization beam splitter.
[0041] In addition, in using SFG or DFG as a nonlinear optical effect, the non-linear optical materials which can be used according to the polarization direction of a lightwave signal and a sampling light pulse differ. When the polarization directions of both light are parallel, and polarization of two basic light is parallel, it is necessary to use the secondary non-linear optical material which performs "type I phase matching" which cross-correlation light generates efficiently. On the other hand, when the polarization direction of both light is a rectangular cross, and polarization of two basic light is a rectangular cross, it is necessary to use the secondary non-linear optical material which performs "type II phase matching" which cross-correlation light generates efficiently (the above-mentioned reference 2). In using FWM as a nonlinear optical effect, in order to generate cross-correlation light efficiently, it is necessary to set the polarization direction of a lightwave signal and a sampling light pulse as parallel.
[0042] Moreover, what is necessary is just to amplify the peak power of a lightwave signal and a sampling light pulse with the light amplifier arranged before and after the optical multiplexing machine 2, if the conversion efficiency of the non-linear optical material 3 to be used is inadequate. As a light amplifier, the light amplifier and semiconductor laser amplifier using the rare earth addition fiber which added rare earth can be used.
[0043] Moreover, a lightwave signal and a sampling light pulse are contained in the output light of a non-

linear optical material 3 besides the sum cycle light (or difference cycle light or 4 light-wave mixing light) which is a cross-correlation lightwave signal. Moreover, depending on conditions, the second higher harmonic of a lightwave signal or a sampling light pulse may also be generated. What is necessary is to insert the wavelength filter 32 between a non-linear optical material 3 and an optical/electrical converter 4, and to choose only a cross-correlation lightwave signal, in degrading the signal-to-noise ratio of the cross-correlation lightwave signal which such light measures.
[0044] (The 2nd operation gestalt: Claims 1, 7, 10, 11, and 13) Drawing 11 shows the 2nd operation gestalt of the lightwave signal quality monitor of this invention. It replaces with the timing clock generating means 11 of the 1st operation gestalt, and the description of this operation gestalt is the basic clock frequency f0. It is in the configuration using a timing clock generating means 16 to generate the timing clock of f0-/n1-deltaf (or f0/n1+deltaf), from the synchronous-network clock signal which has clock frequency f0 / m of 1 for an integer (m= 1, 2, --). In addition, what is necessary is just to set up offset frequency deltaf based on the above-mentioned (11) types. Other configurations are the same as that of the 1st operation gestalt.
[0045] The configuration of the timing clock generating means 16 is drawing 9 (b). It is the network synchronization clock signal of bit rate f0 / m to the basic clock frequency f0 so that it may be shown. What is necessary is just to use a basic bit rate timing generation means 17 to generate the clock frequencies f0/n1 of 1 for an integer.
[0046] Moreover, as it replaces with the timing clock generating means 11 (drawing 9 (a)) of the 1st operation gestalt, and the timing clock generating means 16 (drawing 9 (b)) of the 2nd operation gestalt and is shown in drawing 9 (c) From the clock frequencies f0/n1 of 1 for an integer of a basic clock frequency (11) The oscillator which oscillates timing clock f<SUB>0-/n1-deltaf or f0-/n1+deltaf which adjusted offset frequency deltaf of a formula may be used as a timing clock generating means (claim 12).
[0047] (The 3rd operation gestalt: Claims 1, 7, 8, 13, and 14) Drawing 12 shows the 3rd operation gestalt of the lightwave signal quality monitor of this invention. Generally the nonlinear optical effect used by this invention has the polarization dependency, and the cross-correlation lightwave signal power generated according to the polarization condition of the lightwave signal to input changes. This operation gestalt has the composition of removing this polarization dependency.
[0048] Namely, an input and an output use two ports of a certain polarization beam splitters 21 at a time as an optical multiplexing machine 2 in the 1st operation gestalt. Input a lightwave signal and a sampling light pulse train into each input port, and a non-linear optical material 3-1, 3-2, the wavelength filter 32-1, 32-2, an optical/electrical converter 4-1, and 4-2 are connected to each output port. It is the configuration of adding the cross-correlation electrical signal outputted from each optical/electrical converter in an adder circuit 22, and inputting it into the electrical signal processing means 5.
[0049] Here, polarization of the sampling light pulse train inputted into the polarization beam splitter 21 is set as the linearly polarized light which inclined 45 degrees to the polarization main shaft of the polarization beam splitter 21. At this time, the lightwave signal inputted into the polarization beam splitter 21 and a sampling light pulse train are divided into two polarization components (Psig.p, Psig.s), and (Psam.p and Psam.s) which intersect perpendicularly, respectively. And polarization composition is carried out and components (Psig.p, Psam.s), and (Psig.s and Psam.p) which intersect perpendicularly mutually [2 light] are outputted to each output port. The lightwave signal and sampling light pulse train which were outputted to each output port are changed into a cross-correlation lightwave signal by the non-linear optical material 3-1 prepared according to the individual, respectively, and 3-2, and are further changed into a cross-correlation electrical signal by the optical/electrical converter 4-1 and 4-2. These two cross-correlation electrical signals are added in an adder circuit 22, are inputted into the electrical signal processing means 5, are processed like the 1st operation gestalt, ask for the signal-to-noise-ratio multiplier Q, and inspect the quality of a lightwave signal.
[0050] With this operation gestalt, two polarization component Psam.p after the polarization beam splitter 21 and Psam.s are made equal by making polarization of a sampling light pulse train into the linearly polarized light which inclined 45 degrees to the polarization main shaft of the polarization beam splitter 21. That is, it is Psam about all the power of a sampling light pulse train. When it carries out, it is Psam.p=Psam.s= 0.5Psam. -- It is set to (12). On the other hand, the polarization condition at the time of carrying out incidence of the lightwave signal to the polarization beam splitter 21 is not being fixed. Therefore, a lightwave signal is divided into two polarization component Psig.p of the power ratio of arbitration, and Psig.s by the polarization beam splitter 21. However, it is fixed and the sum of these two

components is Psig about all the power of a lightwave signal. It is Psig.p+Psig.s=Psig when it carries out. -- It is set to (13).
[0051] The sum total Pint of the power of a cross-correlation lightwave signal which will be generated here in a non-linear optical material 3-1 and 3-2 if conversion efficiency of a nonlinear optical effect is set to eta Pint =etaPsig.p Psam. s+eta Psig.s Psam.p -- It is set to (14). (14) When (12) types and (13) types are substituted for a formula, it is Pint = 0.5etaPsig Psam. -- It is set to (15). This (15) type means that the sum of two cross-correlation lightwave signals is not dependent on the polarization condition of the lightwave signal inputted.
[0052] However, (15) types may not be materialized according to the individual difference of a gap of the branching ratio of the polarization beam splitter 21, and the conversion efficiency of two non-linear optical materials, but a polarization dependency may arise slightly. In this case, what is necessary is just to perform weighting suitably for the level of two cross-correlation electrical signals in an adder circuit 22 so that the level of the added cross-correlation electrical signal may not be dependent on the polarization condition of a lightwave signal.
[0053] By carrying out the monitor of the S/N sequence with such a configuration, quality inspection of the lightwave signal stabilized without not being based on the bit rate of a lightwave signal, and being based on the polarization condition of a lightwave signal can be conducted.
[0054] In addition, also in this operation gestalt, it may replace with the timing clock generating means 11, and a timing clock generating means 16 to generate the timing clock of f0 / n1-deltaf (or f0/n1+deltaf) from the network synchronization clock signal of bit rate f0 / m may be used like the 2nd operation gestalt (claim 10). Moreover, the timing clock generating means which consists of only oscillators as mentioned above may be used (claim 12).
[0055] (The 4th operation gestalt: Claims 1, 7, 8, 13, and 15) Drawing 13 shows the 4th operation gestalt of the lightwave signal quality monitor of this invention. The description of this operation gestalt is replaced with the adder circuit 22 of the 3rd operation gestalt, doubles the timing of two cross-correlation lightwave signals with the optical delay means 23, and is in the configuration which carries out polarization composition by the polarization beam splitter 24 and which is inputted into an optical/electrical converter 4. Other configurations are the same as that of the 3rd operation gestalt.
[0056] (The 5th operation gestalt: Claims 1, 7, 10, and 16) Drawing 14 shows the 5th operation gestalt of the lightwave signal quality monitor of this invention. the 1- with the 4th operation gestalt, in order to inspect the quality of the lightwave signal of a transmission line, it is necessary to branch a part of lightwave signal by the optical turnout 51-1, and loss of the lightwave signal of a transmission line is not avoided. Moreover, if the branching ratio to a monitor system is made low in order to suppress this lightwave signal loss to the minimum, even if it amplifies with a light amplifier, a signal-to-noise ratio will deteriorate and sufficient cross-correlation lightwave signal will not be acquired.
[0057] The description of this operation gestalt is in the configuration which reduces the loss done to the lightwave signal of a transmission line by inputting a sampling light pulse train into a transmission line, generating a cross-correlation lightwave signal, and carrying out wavelength separation of a lightwave signal and the cross-correlation lightwave signal.
[0058] That is, the sampling light pulse train of frequency f0-/n1-deltaf (or f0/n1+deltaf) is repeatedly generated from the network synchronization clock signal of bit rate f0 / m with the timing clock generating means 16 and the short light pulse generating means 12. On the other hand, the optical multiplexing machine 2, a non-linear optical material 3, and the wavelength filter 33 are inserted all over a transmission line, it multiplexs with the optical multiplexing vessel 2, the lightwave signal and sampling light pulse train which have been sent from the transmission line of the upstream are inputted into a non-linear optical material 3, and a cross-correlation lightwave signal is generated.
[0059] The output light of a non-linear optical material 3 is the sum cycle light (optical frequency omegasfg =omega sam+omega sig), difference cycle light (optical frequency omegasfg =omega sam-omega sig), or 4 light-wave mixing light (optical frequency omegafwm =2omega sam-omega sig) which is a lightwave signal (optical frequency omegasig), a sampling light pulse (optical frequency omegasam), and a cross-correlation lightwave signal. Moreover, depending on conditions, the second higher harmonic (optical frequency sig of 2omega) of a lightwave signal and the second optical frequency (sam) higher harmonic of 2omega of a sampling light pulse may occur. The wavelength filter 33 separates a lightwave signal and a cross-correlation lightwave signal into a different port according to an individual from such light. And the

separated lightwave signal is sent out to a down-stream transmission line, a cross-correlation lightwave signal is inputted into an optical/electrical converter 4, and it changes into a cross-correlation electrical signal, and it processes like the 1st operation gestalt with the electrical signal processing means 5, and asks for the signal-to-noise-ratio multiplier Q, and the quality of a lightwave signal is inspected.
[0060] Quality inspection of a lightwave signal can be conducted without not being based on the bit rate of a lightwave signal, and degrading the S/N of the lightwave signal of a transmission line by carrying out the monitor of the S/N sequence with such a configuration.
[0061] (The 6th operation gestalt: Claims 1, 7, 10, 16, and 17) Drawing 15 shows the 6th operation gestalt of the lightwave signal quality monitor of this invention. The description of this operation gestalt is in the configuration which combined the 3rd operation gestalt and the 5th operation gestalt. That is, it has the composition of it not being dependent on the polarization condition of a lightwave signal, and reducing loss of the lightwave signal of a transmission line.
[0062] Incidence of the lightwave signal sent from the transmission line of the upstream and the sampling light pulse train is carried out from input port which is different in the polarization beam splitter 21. At this time, polarization of a sampling light pulse train is set as the linearly polarized light which inclined 45 degrees to the polarization main shaft of the polarization beam splitter 21. In the polarization beam splitter 21, it separates into two polarization components (Psig.p, Psig.s), and (Psam.p, Psam.s) which intersect perpendicularly, and a lightwave signal and a sampling light pulse train are outputted to the components (Psig.p, Psam.s) which intersect perpendicularly mutually [2 light], and the output port where polarization composition is carried out and Psig.s differs from (Psam.p), respectively.
[0063] The lightwave signal and sampling light pulse train which were outputted to each output port are changed into a cross-correlation lightwave signal by the non-linear optical material 3-1 prepared according to the individual, respectively, and 3-2, and are further divided into a lightwave signal and a cross-correlation lightwave signal by the wavelength filter 33-1 and 33-2, respectively. Two separated lightwave signals double timing with the optical delay means 25, carry out polarization composition by the polarization beam splitter 26, and are sent out to the transmission line of the downstream. On the other hand, two separated cross-correlation lightwave signals are changed into a cross-correlation electrical signal by the optical/electrical converter 4-1 and 4-2, respectively, are added further in an adder circuit 22, are inputted into the electrical signal processing means 5, are processed like the 1st operation gestalt, ask for the signal-to-noise-ratio multiplier Q, and inspect the quality of a lightwave signal.
[0064] Quality inspection of the lightwave signal stabilized without being further based on the polarization condition of a lightwave signal can be conducted without not being based on the bit rate of a lightwave signal, and degrading the S/N of the lightwave signal of a transmission line by carrying out the monitor of the S/N sequence with such a configuration.
[0065] (The 7th operation gestalt: Claims 1, 7, 10, 16, and 18) Drawing 16 shows the 7th operation gestalt of the lightwave signal quality monitor of this invention. The description of this operation gestalt is in the configuration which combined the 4th operation gestalt and the 5th operation gestalt. That is, it has the composition of it not being dependent on the polarization condition of a lightwave signal, and reducing loss of the lightwave signal of a transmission line.
[0066] It is the configuration of replacing with the adder circuit 22 of the 6th operation gestalt, doubling the timing of two cross-correlation lightwave signals with the optical delay means 23 in this operation gestalt, carrying out polarization composition by the polarization beam splitter 24, and inputting into an optical/electrical converter 4. Other configurations are the same as that of the 6th operation gestalt.
[0067] (The 8th operation gestalt: Claim 2) Drawing 17 shows the 8th operation gestalt of the lightwave signal quality monitor of this invention. drawing -- setting -- a transmission line to basic clock frequency f0 The lightwave signal which has bit rate N and f0 (bit/s) of the integral multiple of (Hz) (N= 1, 2, --) is inputted, and a part of the lightwave signal branches by the optical turnout 51. At this time, in order to oppress transmission characteristic degradation by branching loss, the smaller possible one of the branching ratio of the monitor port to a transmission-line port is good. The lightwave signal which branched by the optical turnout 51 is changed into an electrical signal with an optical/electrical converter 61, and is inputted into the electrical signal processing means 62. In addition, what is necessary is just to amplify using a light amplifier, if the reinforcement of the lightwave signal inputted into an optical/electrical converter 61 is insufficient.
[0068] The timing clock generating means 63 is the basic clock frequency f0. Frequency f0-/n1-deltaf

which adjusted offset frequency deltaf (Hz) from 1 for an integer of (Hz) (Hz) or f0/n1+deltaf The timing clock of (Hz) is generated. In addition, the timing clock generating means 63 is drawing 9 (a) and (b). The shown configuration or drawing 9 (c) Any of the configuration of only the shown oscillator are sufficient (claims 9, 11, and 12). In addition, drawing 9 (a) In taking a configuration, an optical turnout is arranged between the optical turnout 51 and an optical/electrical converter 61, and it inputs the branched lightwave signal into the timing clock generating means 63. Moreover, drawing 9 (b) In taking a configuration, it inputs a synchronous-network clock signal into the timing clock generating means 63.
[0069] The electrical signal processing means 62 samples an electrical signal using this timing clock, and measures the histogram of optical reinforcement. and the sampling point which constitutes the histogram to "level 1" and "level 0" -- the difference of the average-value level within between each existing mean time, and "level 1" and "level 0" -- the time amount from the ratio of the sum of the standard deviation value within each mean time concerned -- average Q value is calculated and the quality of a lightwave signal is inspected.
[0070] The description of this operation gestalt is in the place which performs a sampling in an electric stage instead of the sampling by **** shown in drawing 1 and each above-mentioned operation gestalt. Performance monitoring of the lightwave signal of the bit rate of arbitration can be performed like [the configuration of this operation gestalt] each above-mentioned operation gestalt (claims 3-6). However, the bit rates of the lightwave signal which can respond are dozens Gbit/s by the band and processing speed of an optical/electrical converter or an electrical signal processing means. It is restricted to extent. However, to the optical-fiber-transmission network where it turns out that the highest bit rate does not exceed this limit, it is applicable.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] The block diagram showing the basic configuration of the lightwave signal quality monitor of this invention.
[Drawing 2] Drawing showing the relation of the optical frequency in SFG, DFG, and FWM.
[Drawing 3] Drawing explaining the method of setting up the level of the histogram on the strength [optical] measured with an electrical signal processing means.
[Drawing 4] Drawing explaining the method of determining threshold level.
[Drawing 5] Average Q value and time amount t0 Drawing showing relation with the Q value which can be set.
[Drawing 6] Drawing explaining the method of setting up the level of the histogram on the strength [optical] measured with an electrical signal processing means.
[Drawing 7] Drawing explaining the method of determining threshold level.
[Drawing 8] The block diagram showing the 1st operation gestalt of the lightwave signal quality monitor of this invention.
[Drawing 9] The block diagram showing the example of a configuration of a timing clock generating means.
[Drawing 10] The timing diagram which shows the relation on the time-axis of a lightwave signal, sampling light, and the generated sum cycle light.
[Drawing 11] The block diagram showing the 2nd operation gestalt of the lightwave signal quality monitor of this invention.
[Drawing 12] The block diagram showing the 3rd operation gestalt of the lightwave signal quality monitor of this invention.
[Drawing 13] The block diagram showing the 4th operation gestalt of the lightwave signal quality monitor of this invention.
[Drawing 14] The block diagram showing the 5th operation gestalt of the lightwave signal quality monitor of this invention.
[Drawing 15] The block diagram showing the 6th operation gestalt of the lightwave signal quality monitor of this invention.
[Drawing 16] The block diagram showing the 7th operation gestalt of the lightwave signal quality monitor of this invention.
[Drawing 17] The block diagram showing the 8th operation gestalt of the lightwave signal quality monitor of this invention.
[Drawing 18] The block diagram showing the example of a configuration of the conventional error rate system of measurement.
[Drawing 19] Drawing showing the eye pattern and the histogram on the strength [optical] of a lightwave signal.
[Drawing 20] The block diagram showing the system of measurement of the eye pattern of a lightwave signal.
[Description of Notations]
1 Sampling Light Pulse Generating Means
2 Optical Multiplexing Machine
3 Non-linear Optical Material

4 Optical/electrical Converter
5 Electrical Signal Processing Means
11 16 Timing clock generating means
12 Short Light Pulse Generating Means
13 17 Basic bit rate timing generation means
14 Oscillator
15 Mixer
18 Band Pass Filter
21, 24, 26 Polarization beam splitter
22 Adder Circuit
23 25 Optical delay means
32 33 Wavelength filter
51 Optical Turnout
52 Light Amplifier
61 Optical/electrical Converter
62 Electrical Signal Processing Means
63 Timing Clock Generating Means

[Translation done.]

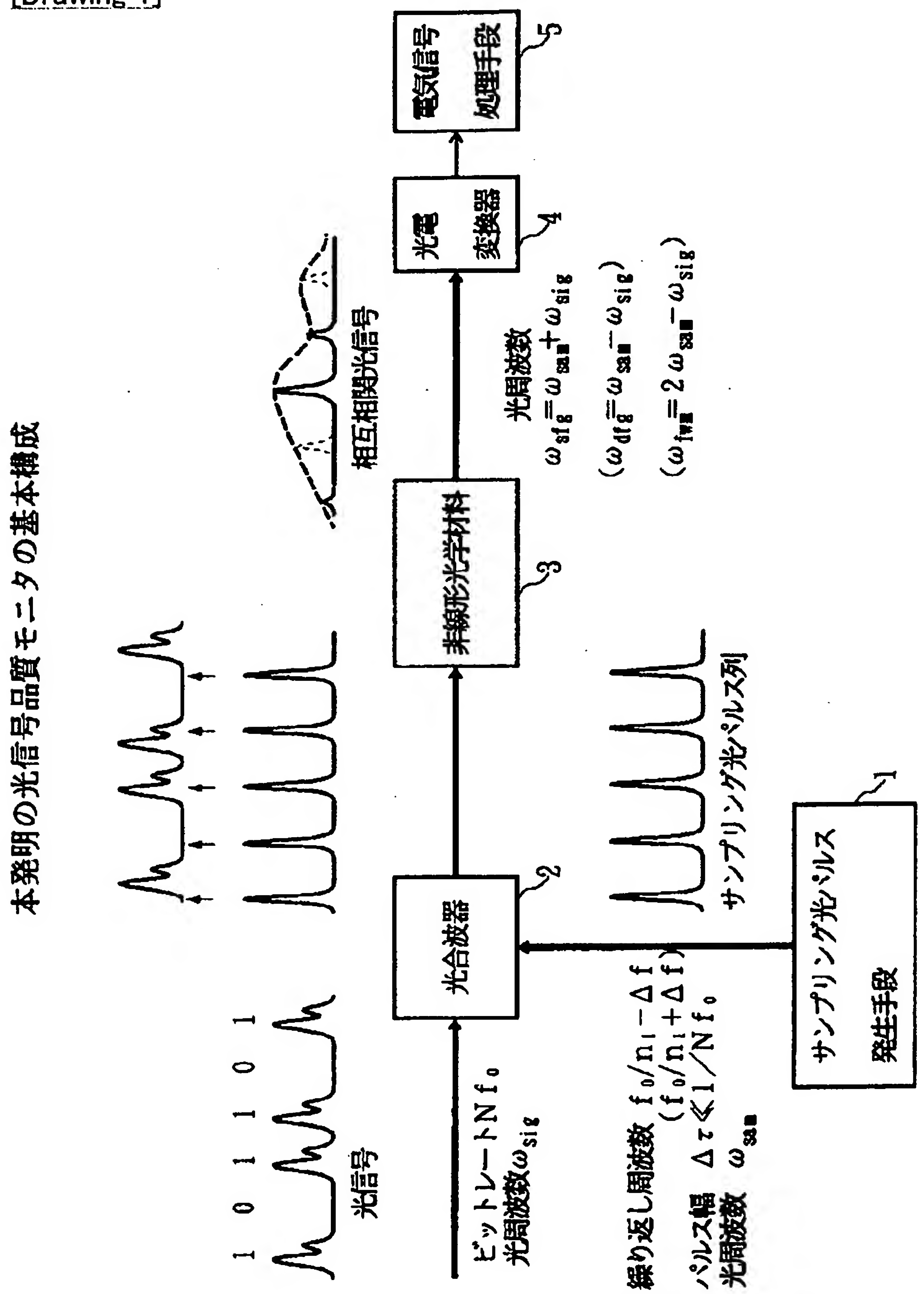
* NOTICES *

1.This document has been translated by computer. So the translation may not reflect the original precisely.

2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

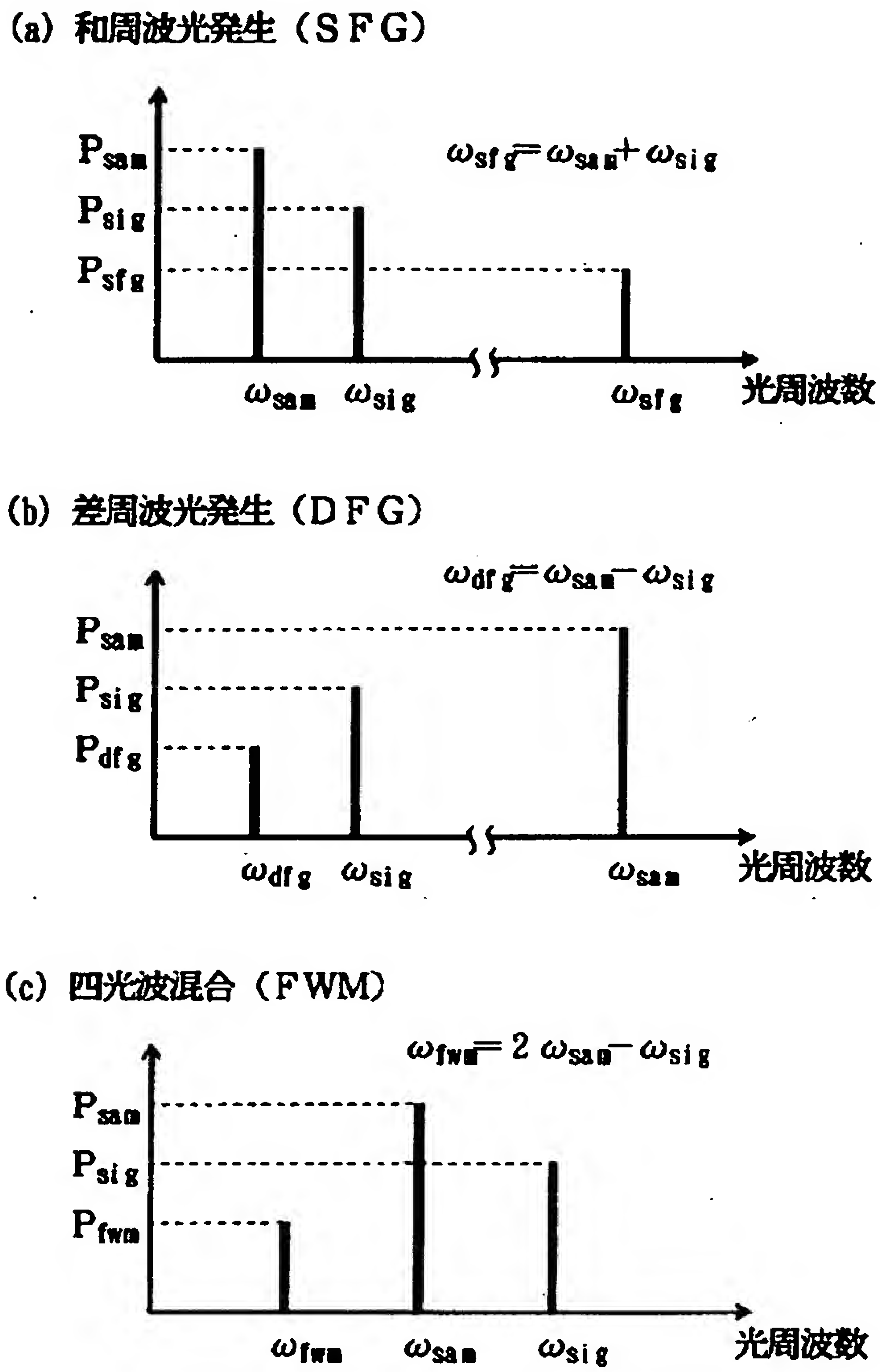
DRAWINGS

[Drawing 1]



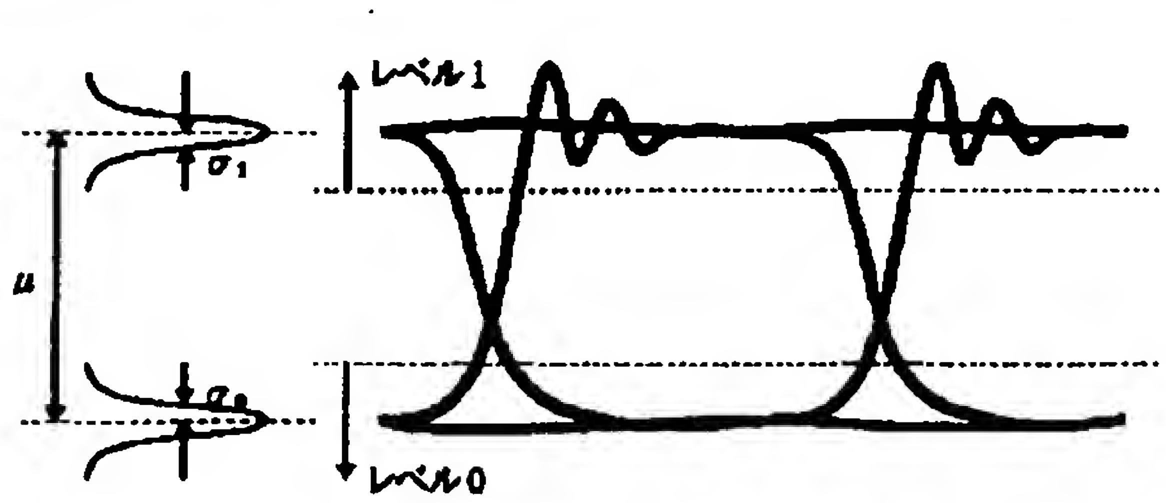
[Drawing 2]

ＳＦＧ，ＤＦＧ，ＦＷＭにおける光周波数の関係

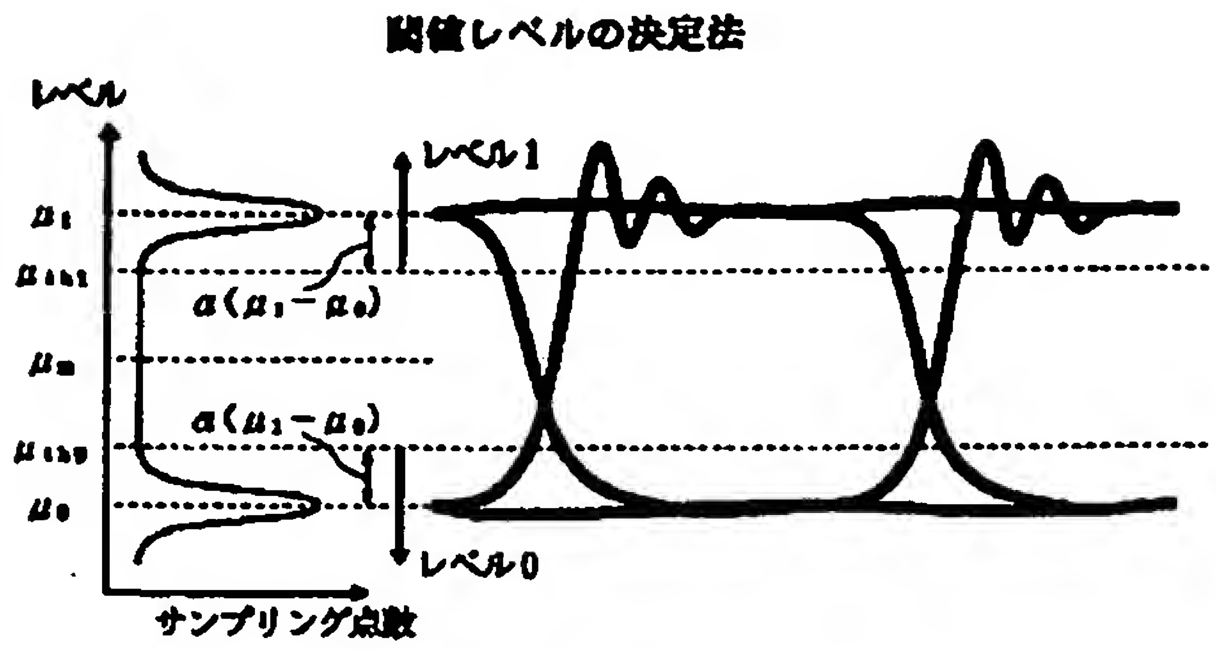


[Drawing 3]

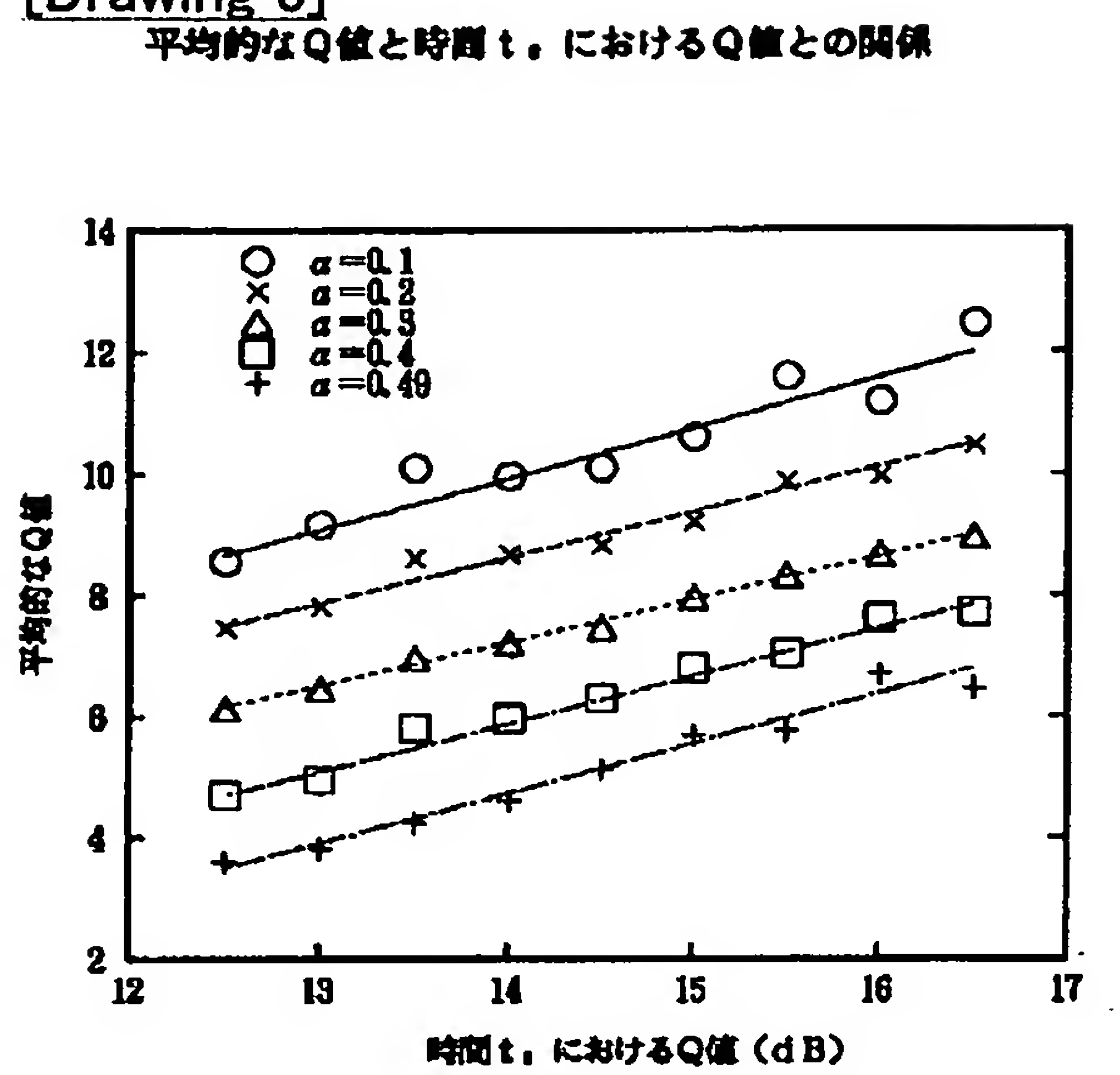
電気信号処理手段で測定される光強度ヒストグラムのレベルの設定法



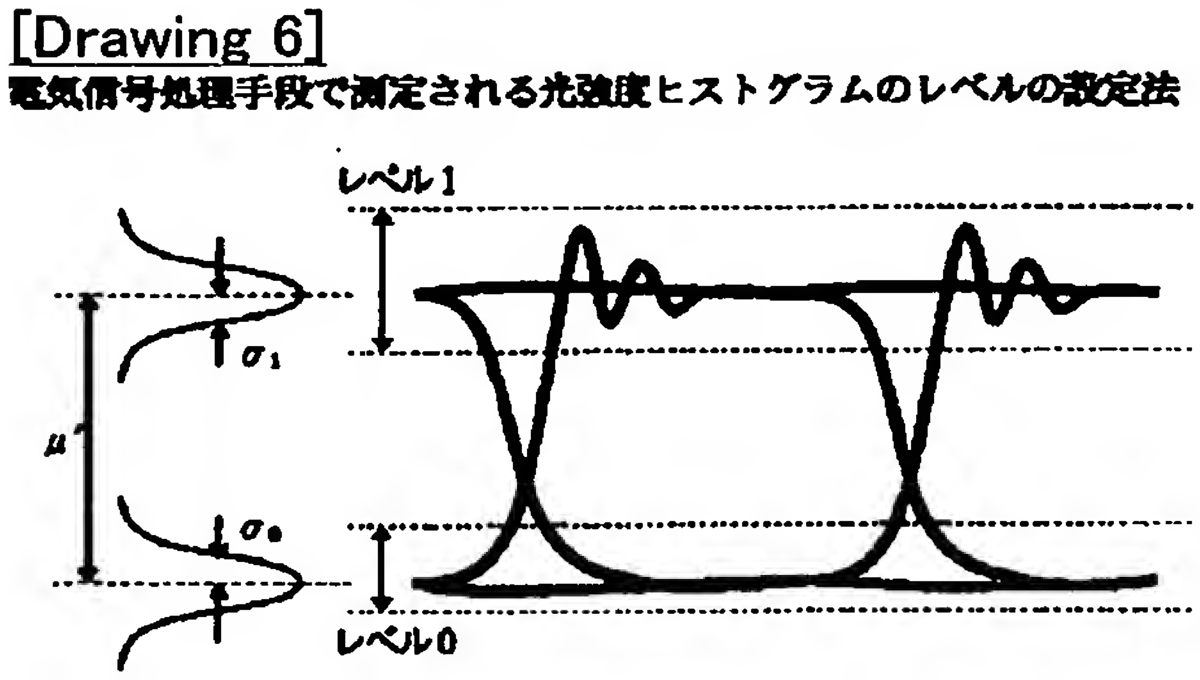
[Drawing 4]



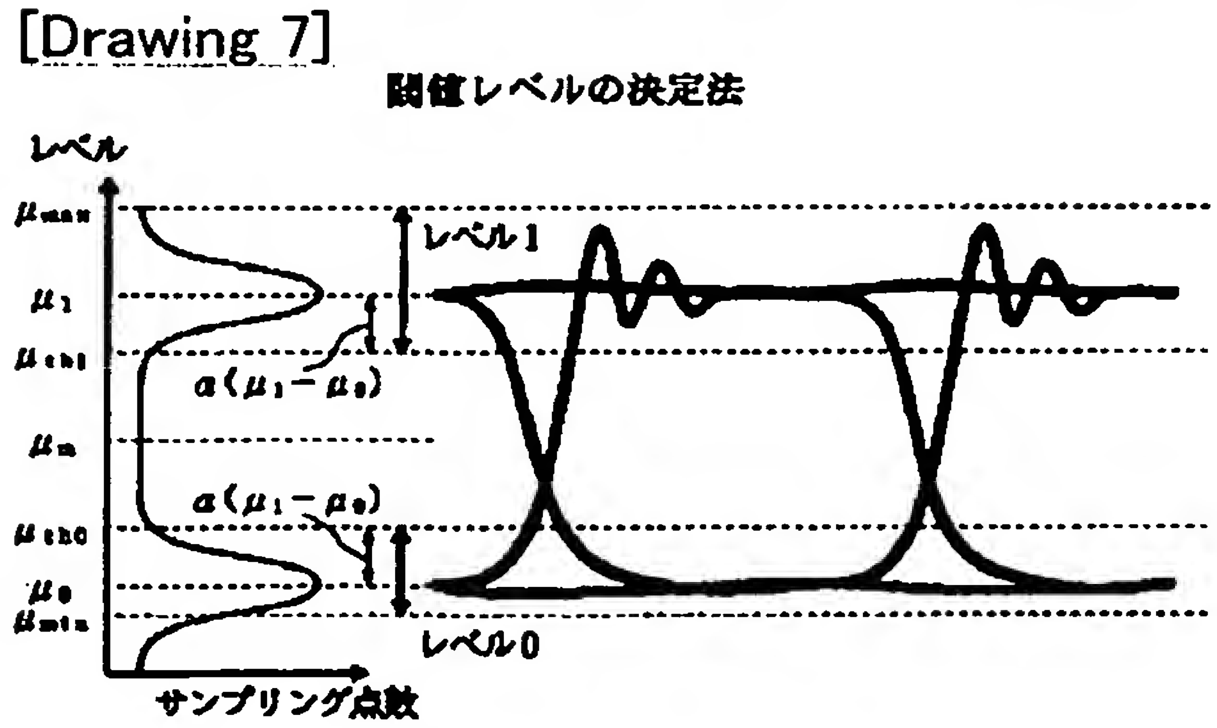
[Drawing 5]



[Drawing 6]



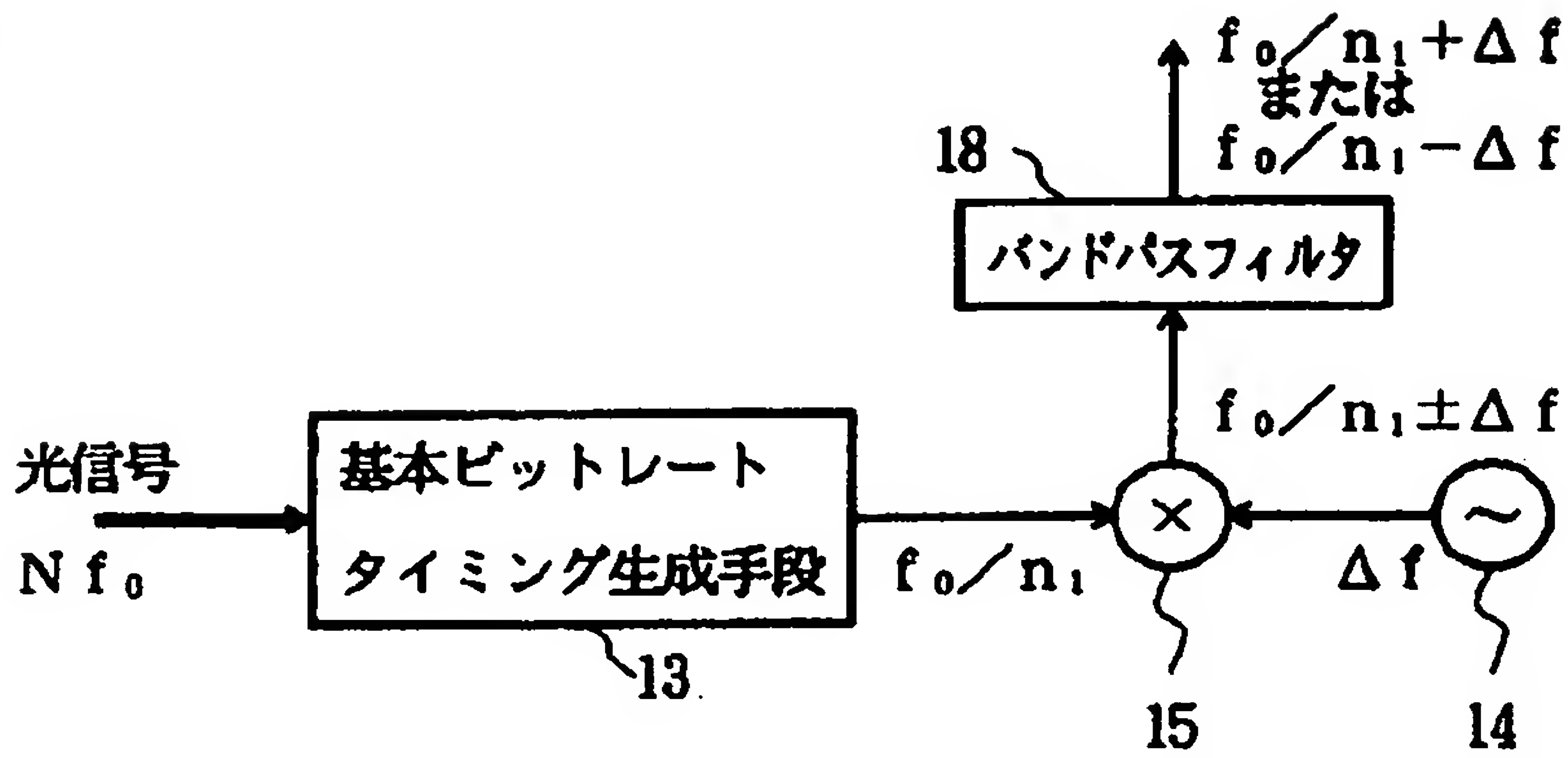
[Drawing 7]



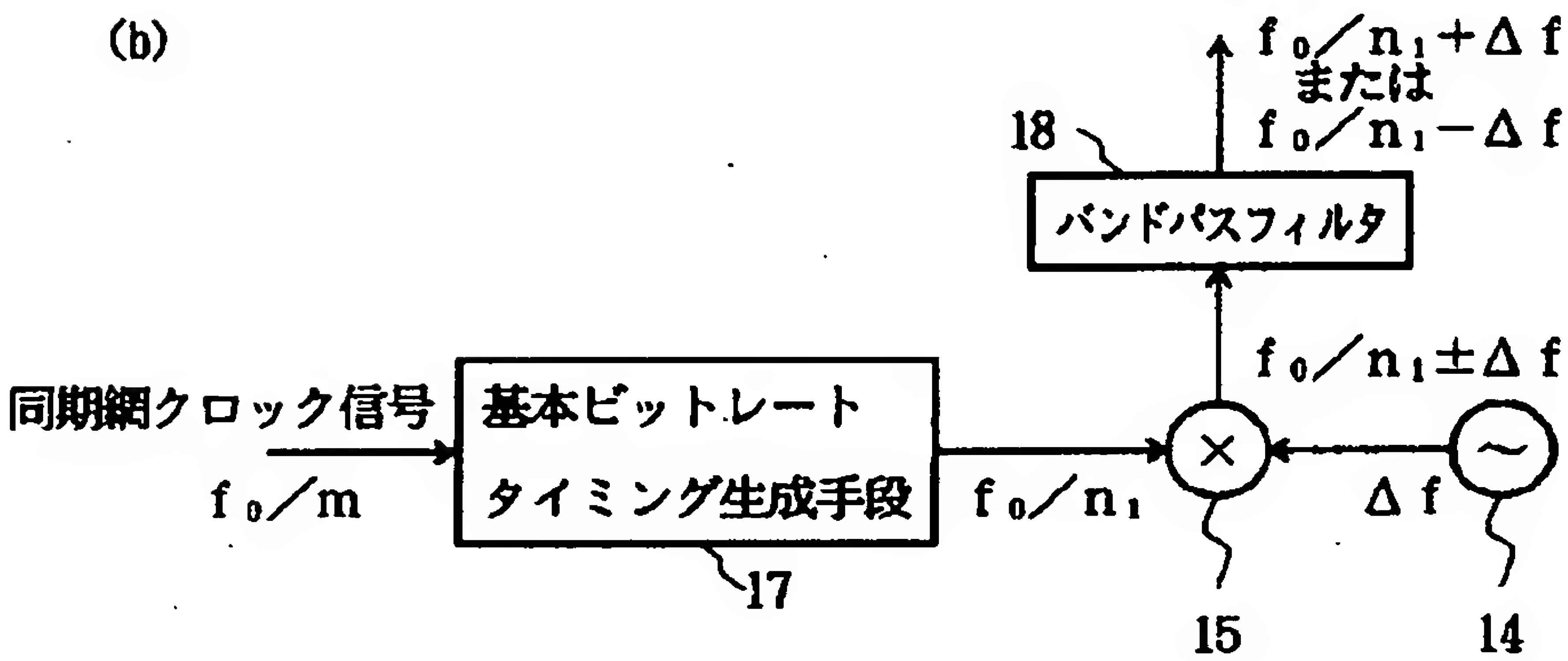
[Drawing 9]

タイミングクロック発生手段の構成例

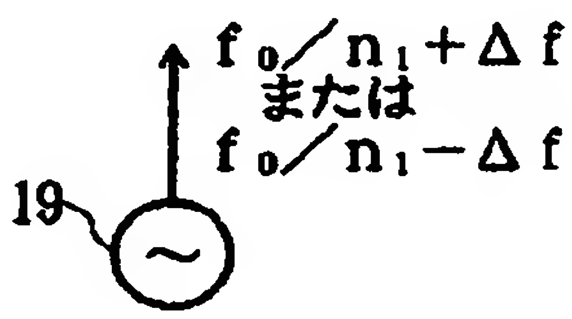
(a)



(b)

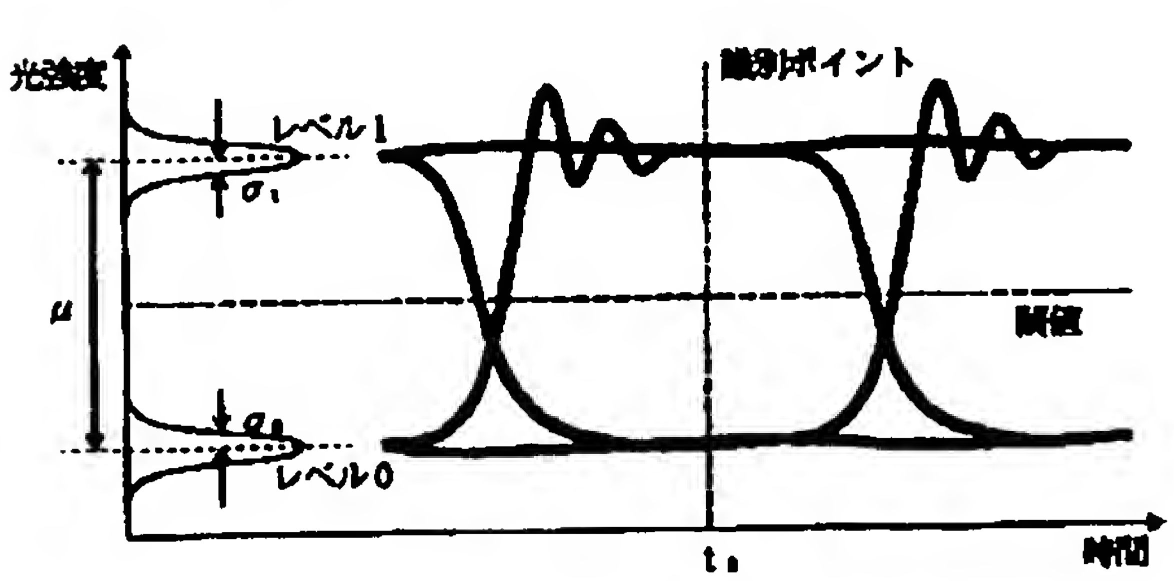


(c)



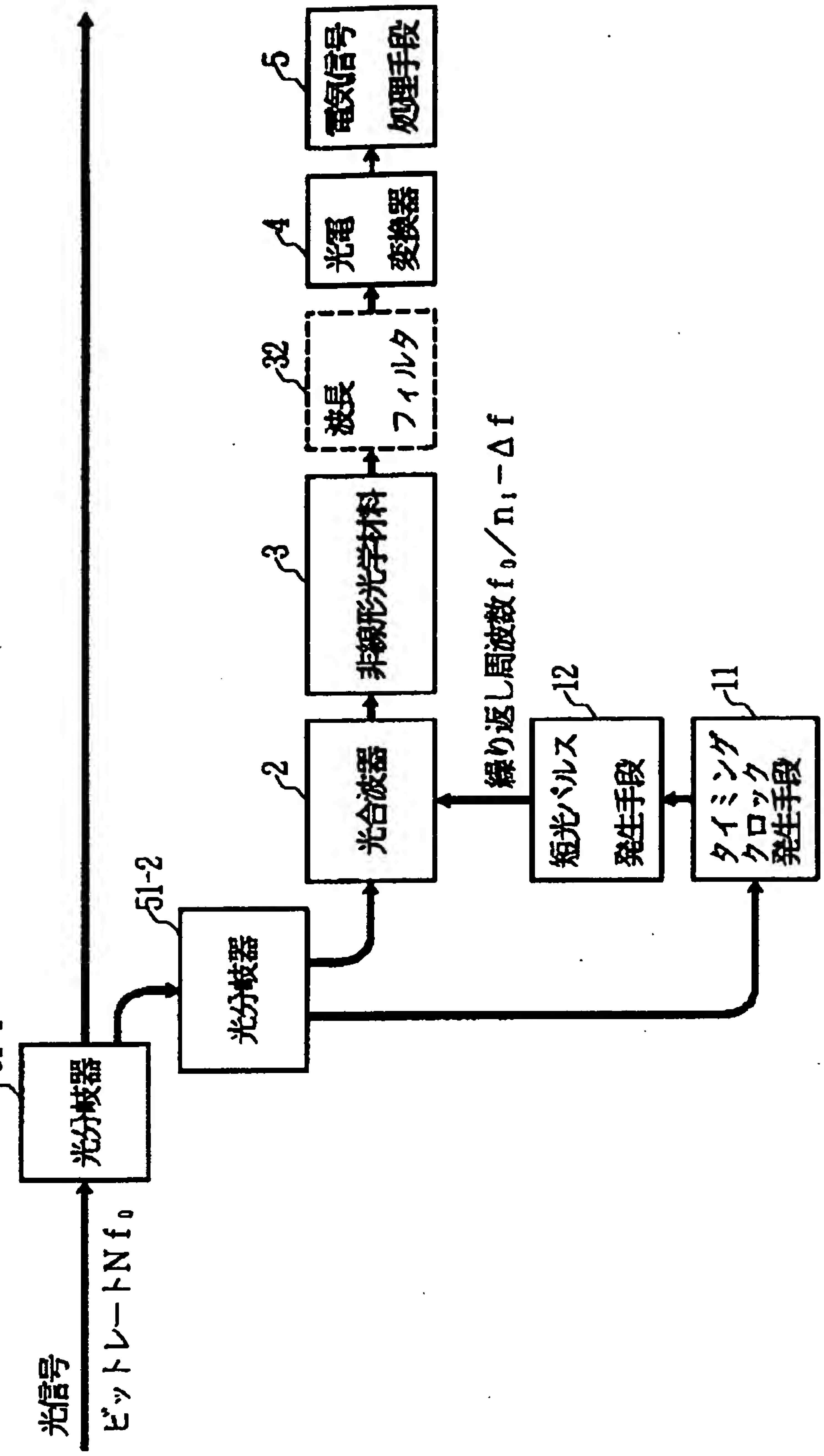
[Drawing 19]

光信号のアイパタンおよび光強度ヒストグラム



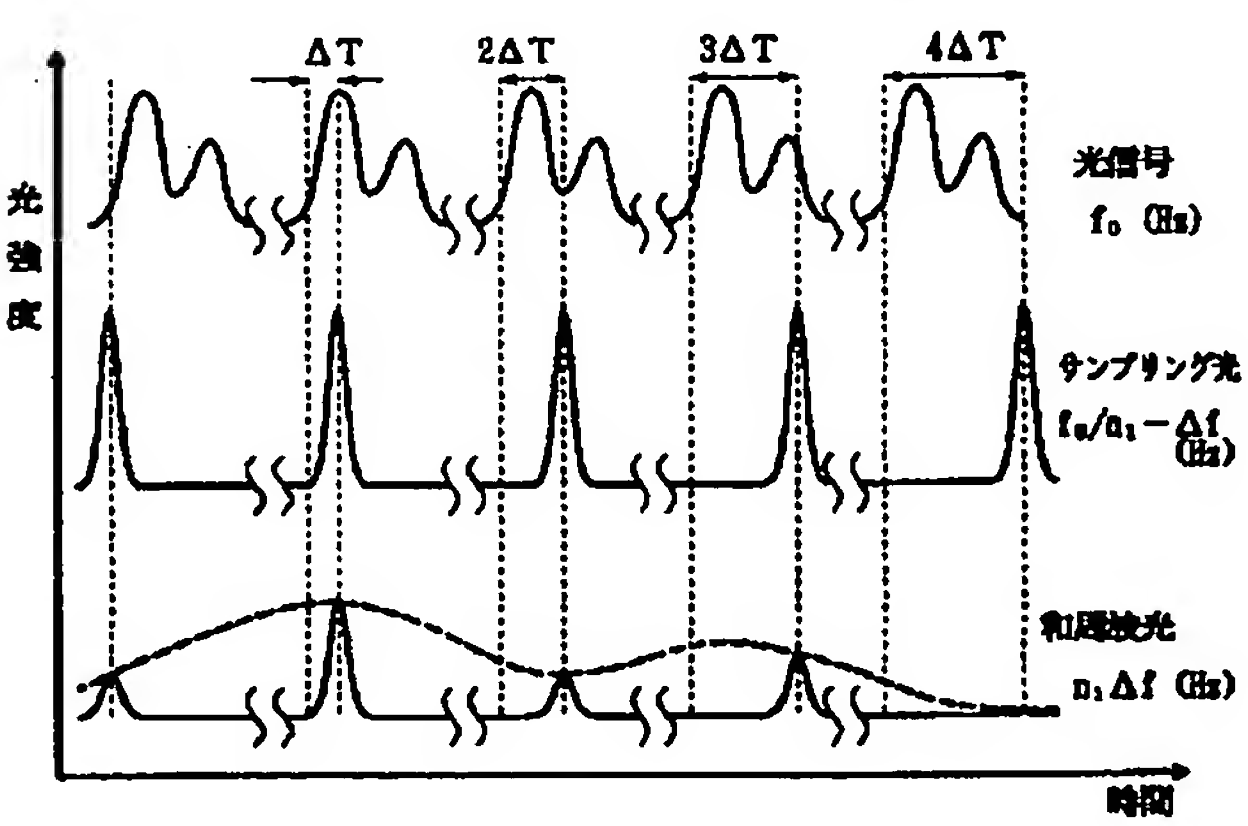
[Drawing 8]

本発明の光信号品質モニタの第１の実施形態



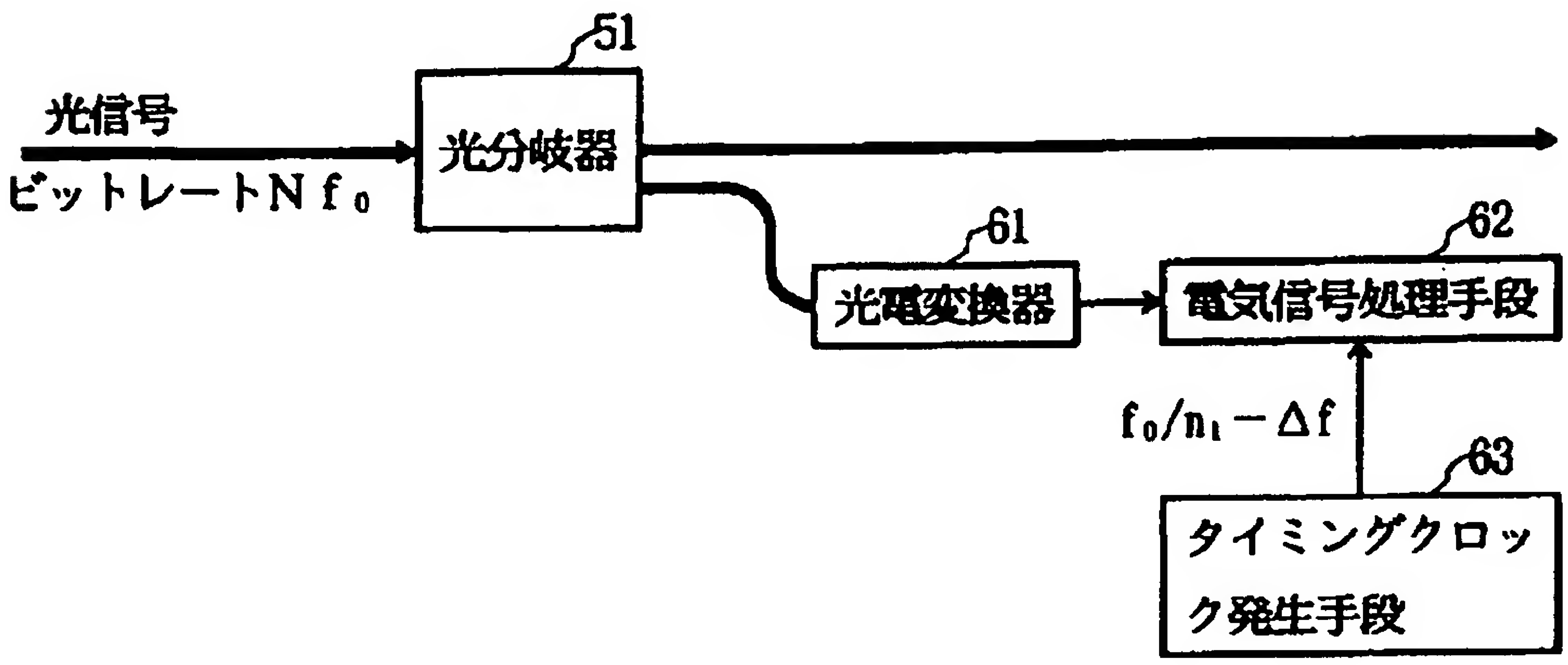
[Drawing 10]

光信号とサンプリング光および発生した和周波光の時間軸上の関係

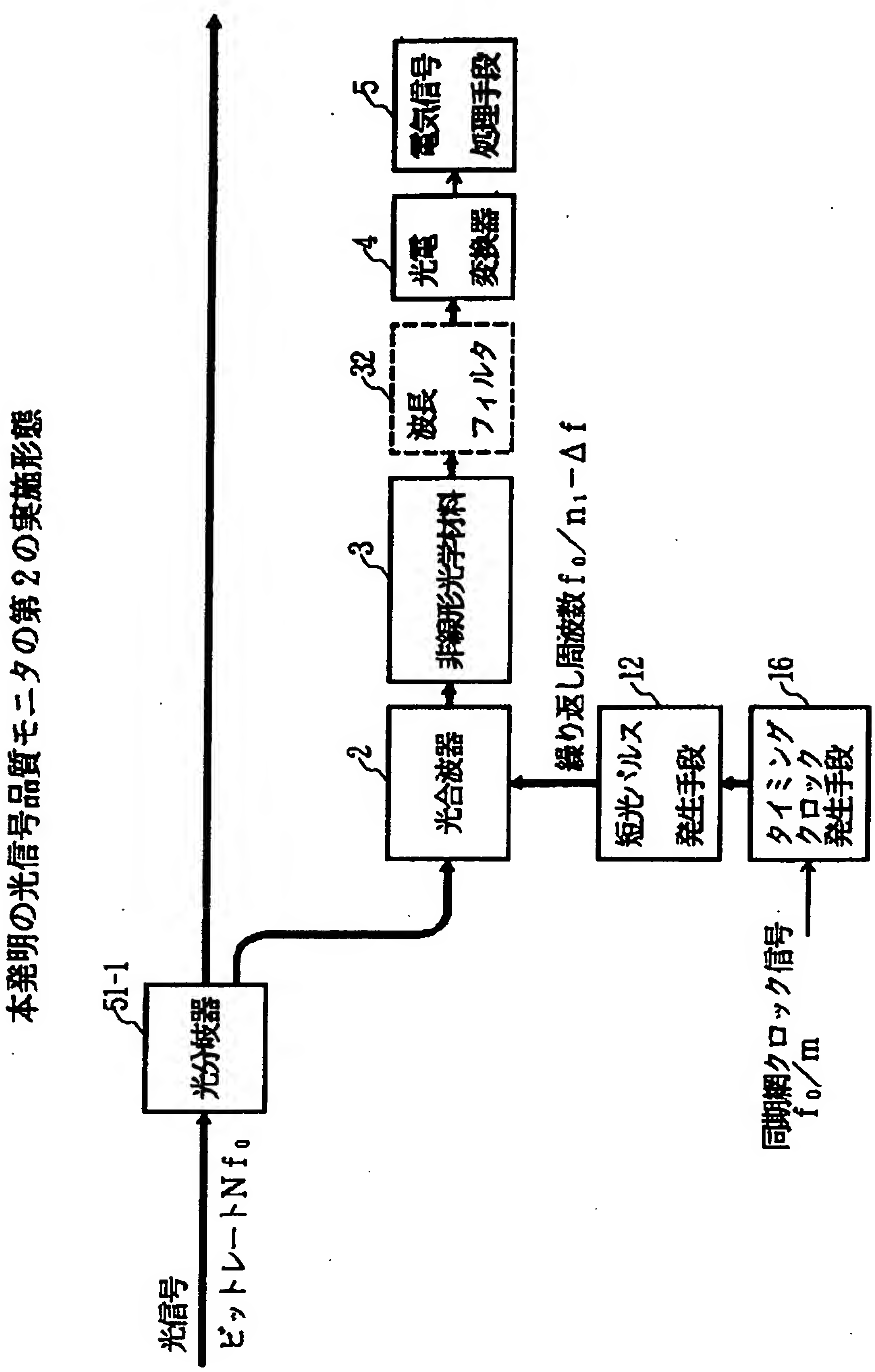


[Drawing 17]

本発明の光信号品質モニタの第８の実施形態

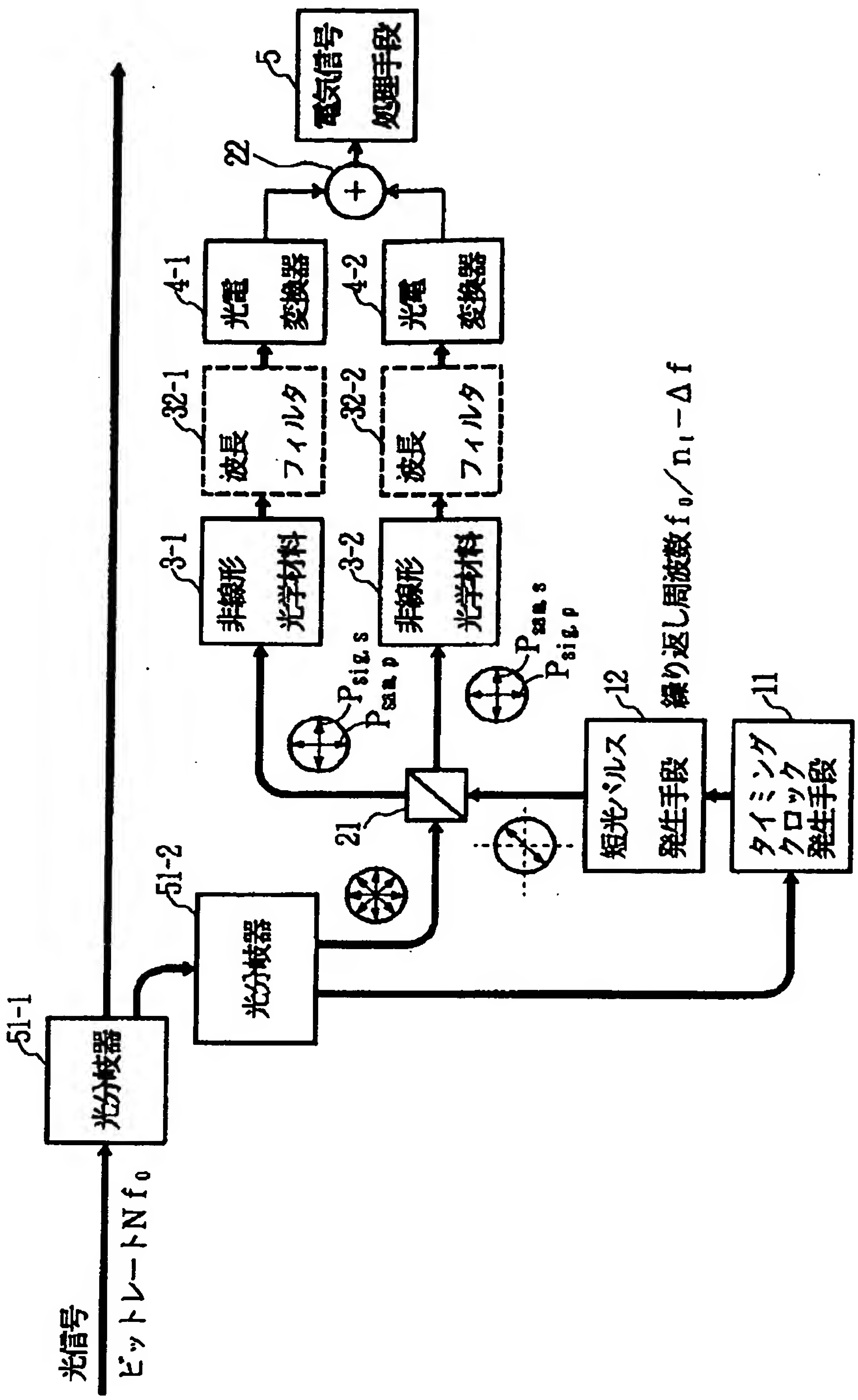


[Drawing 11]


本発明の光信号品質モニタの第２の実施形態
光信号
ビットレートＮｆ０
51-1
光分岐器
2
光合波器
3
非線形光学材料
32
波長フィルタ
4
光電変換器
5
電気信号処理手段
繰り返し周波数ｆ０／ｎ１－Δｆ
12
短光パルス発生手段
16
タイミングクロック発生手段
同期用クロック信号
ｆ０／ｍ

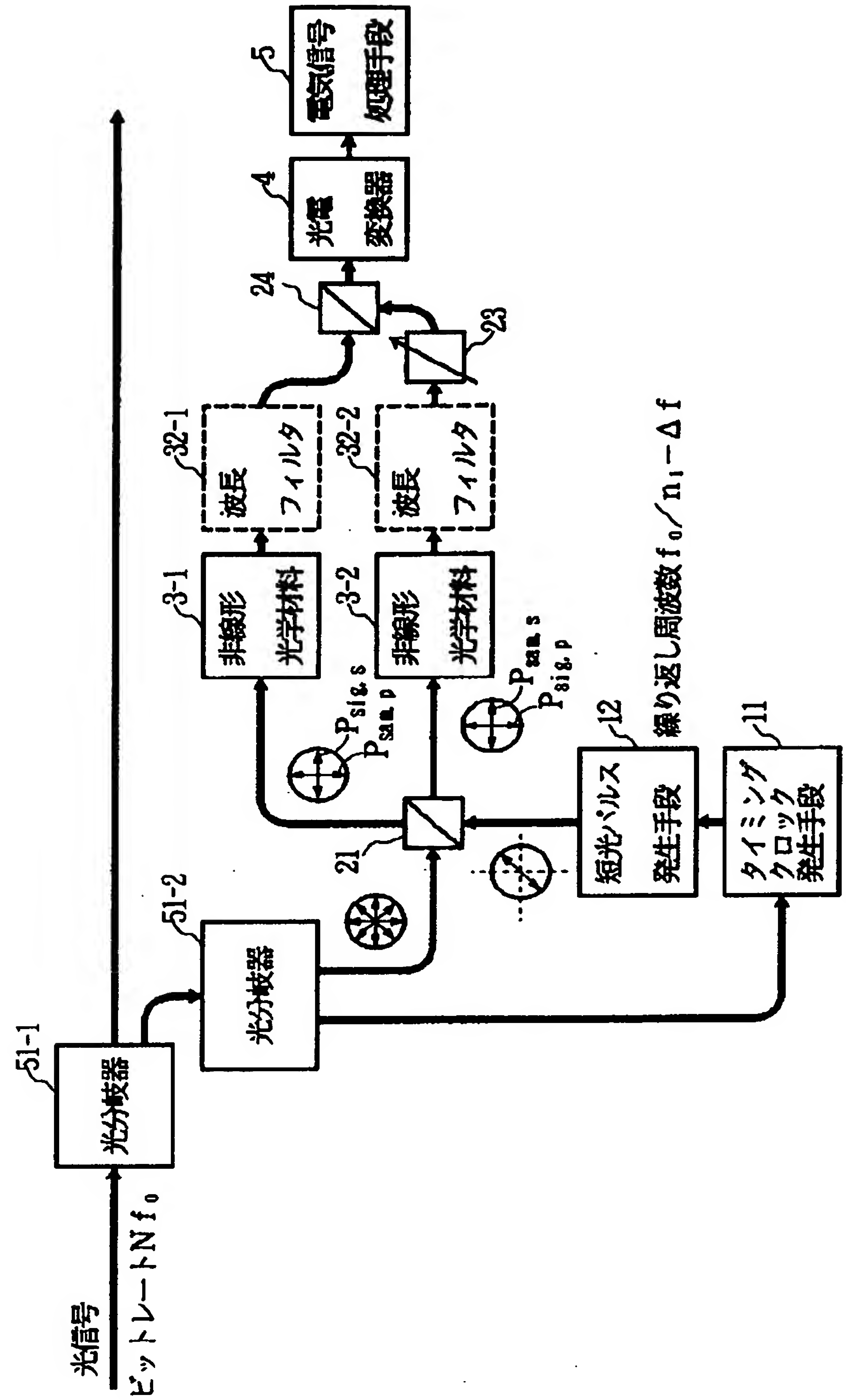
[Drawing 12]

本発明の光信号品質モニタの第3の実施形態



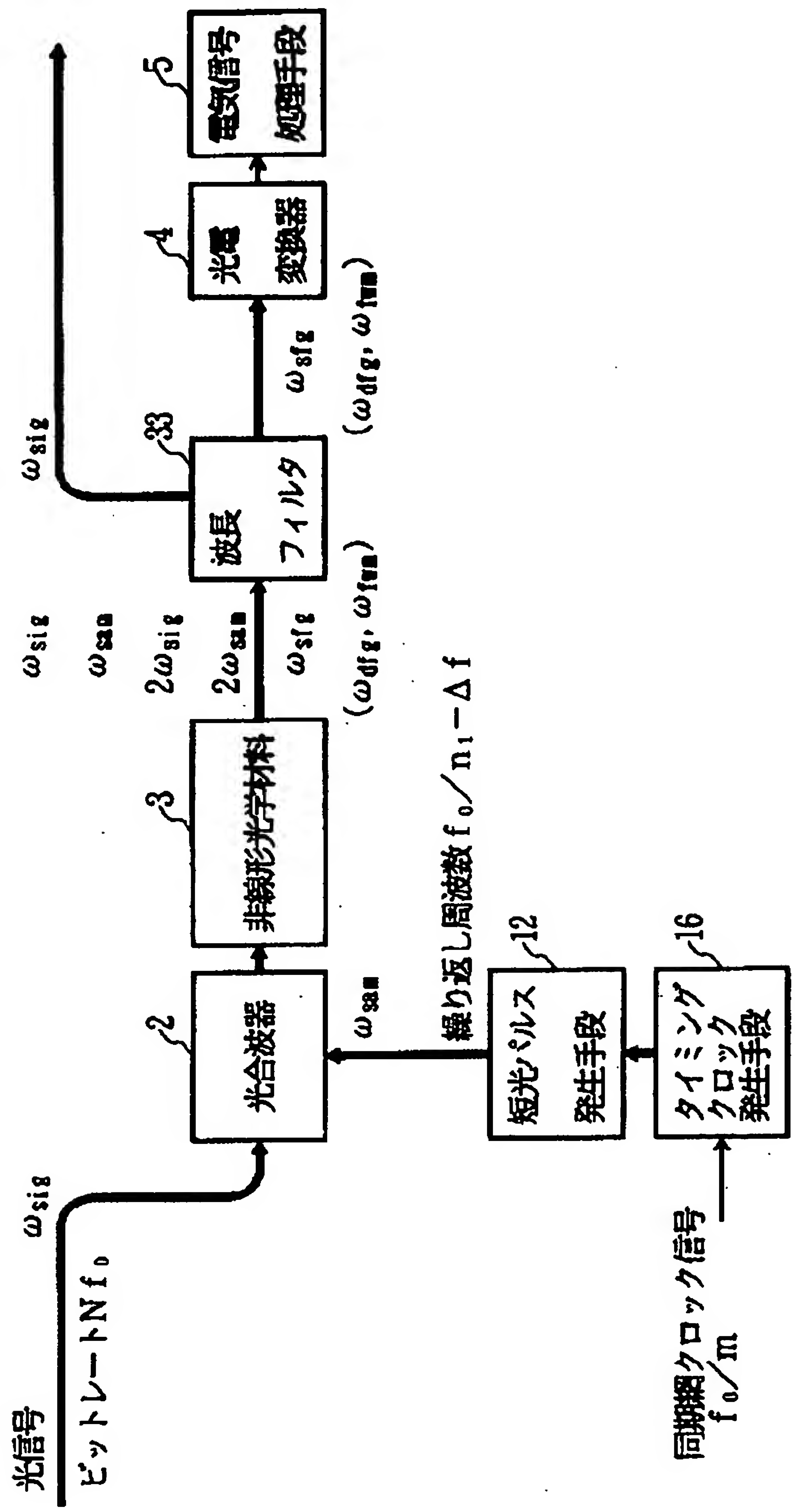
[Drawing 13]

本発明の光信号品質モニタの第４の実施形態



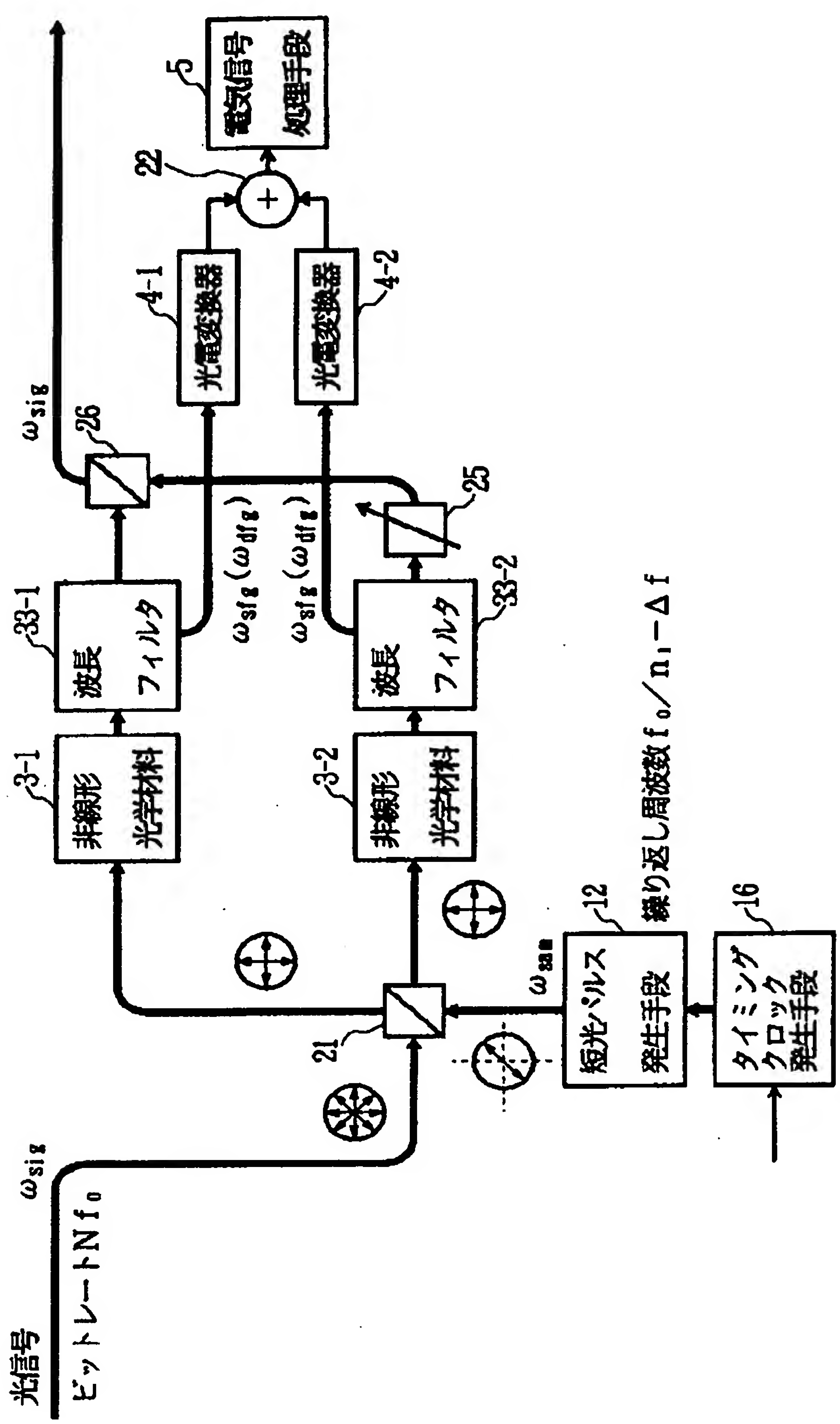
[Drawing 14]

本発明の光信号品質モニタの第５の実施形態



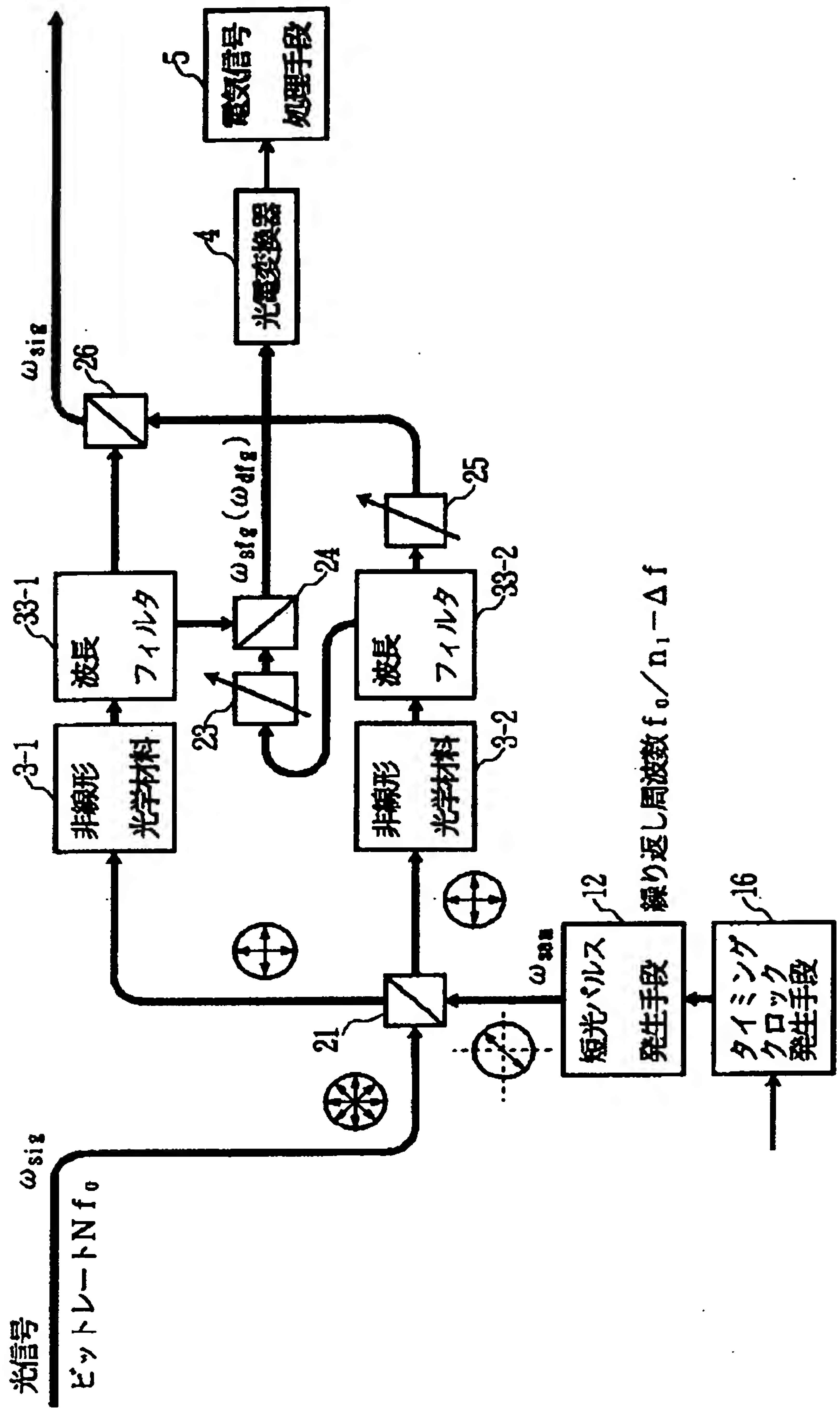
[Drawing 15]

本発明の光信号品質モニタの第６の実施形態



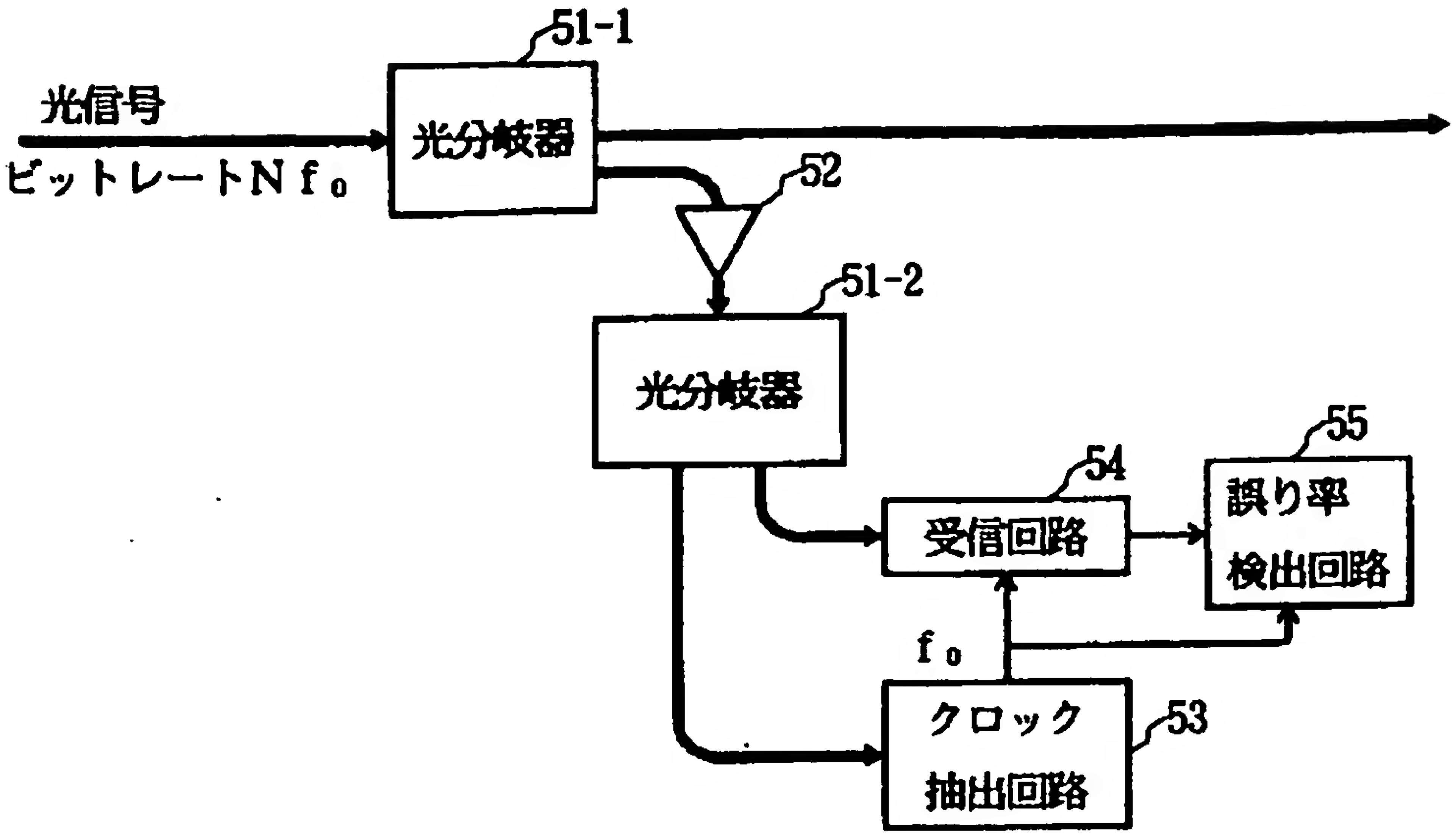
[Drawing 16]

本発明の光信号品質モニタの第７の実施形態



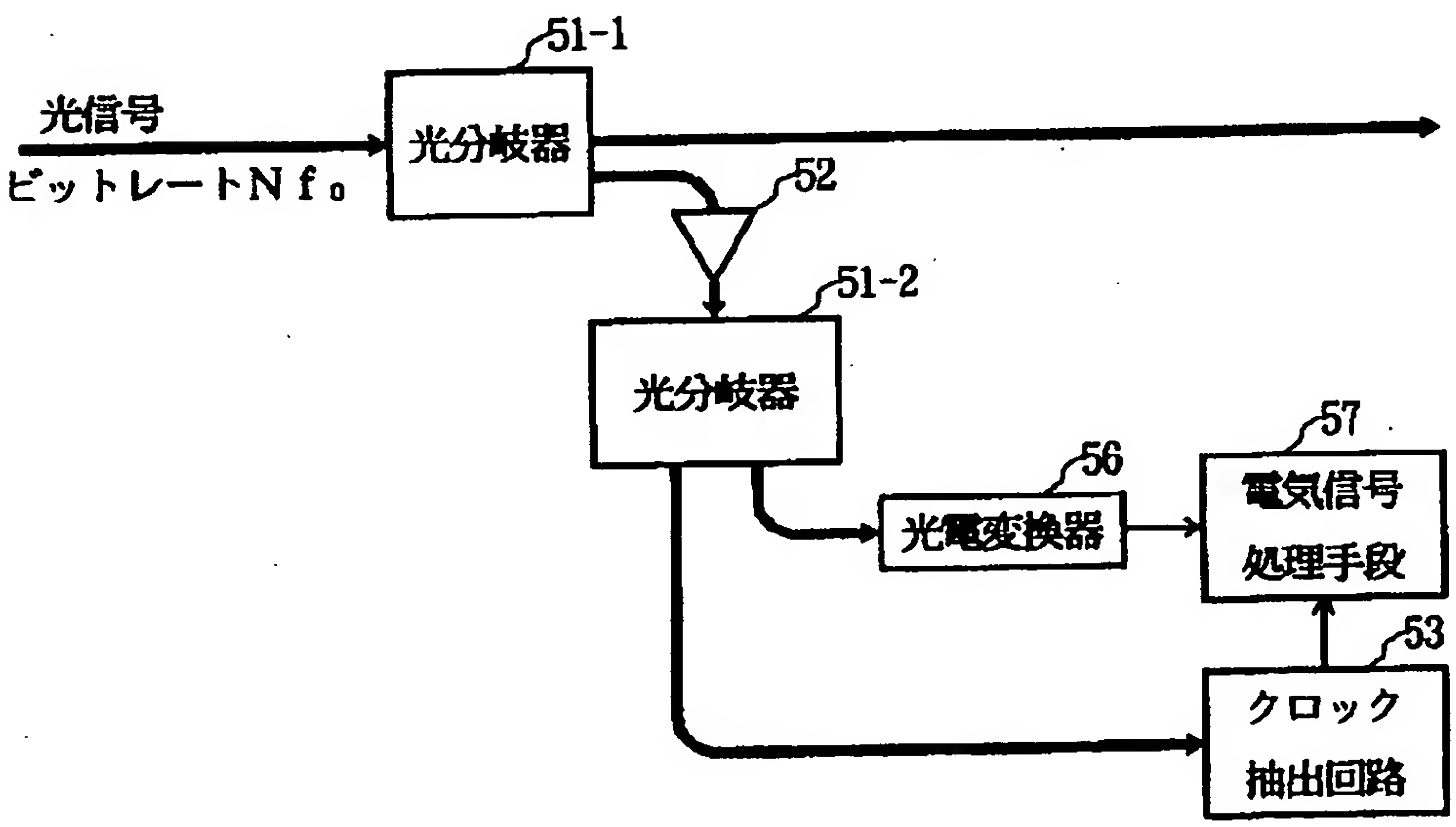
[Drawing 18]

従来の誤り率測定系の構成例



[Drawing 20]

光信号のアイパタンの測定系



[Translation done.]